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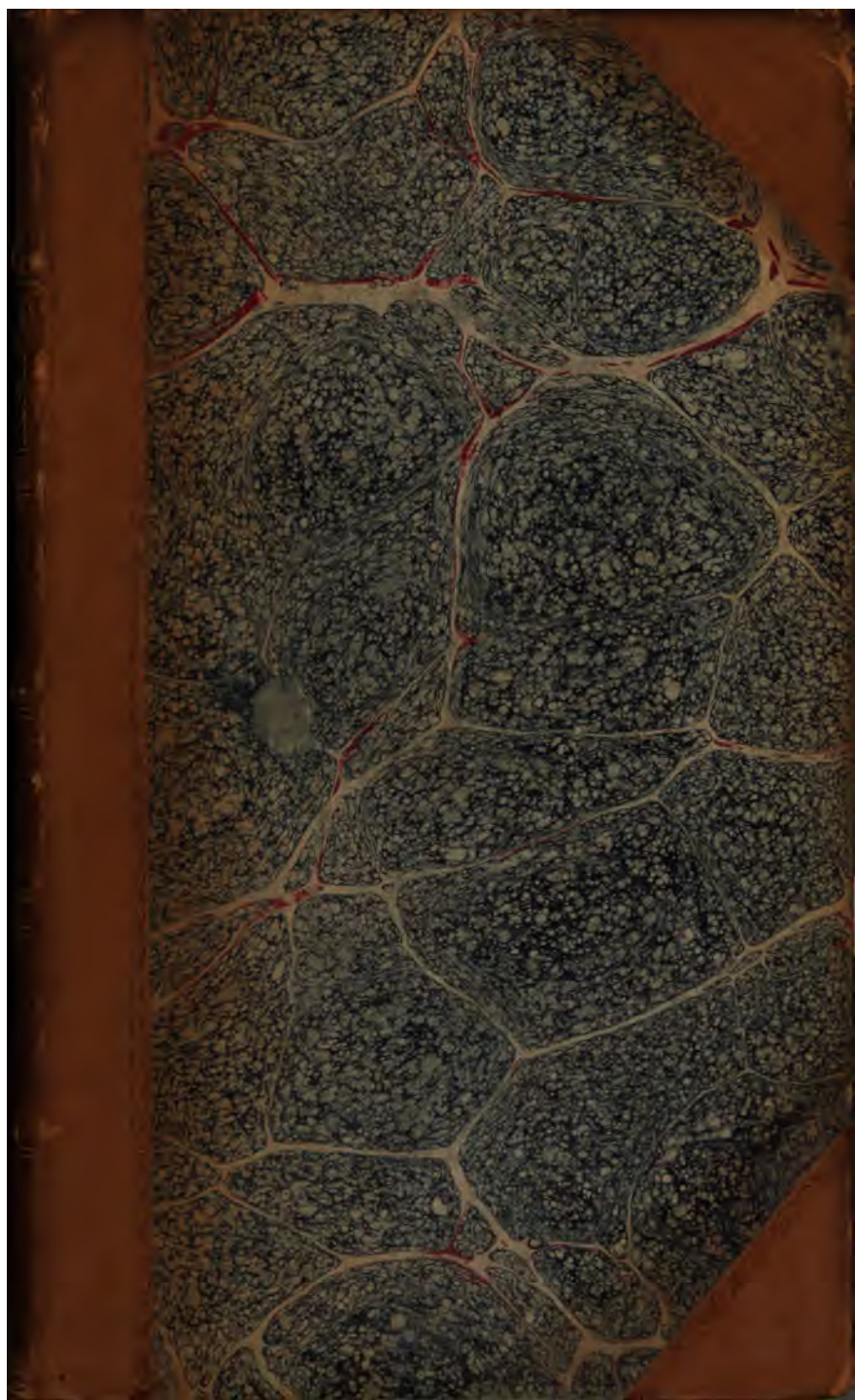
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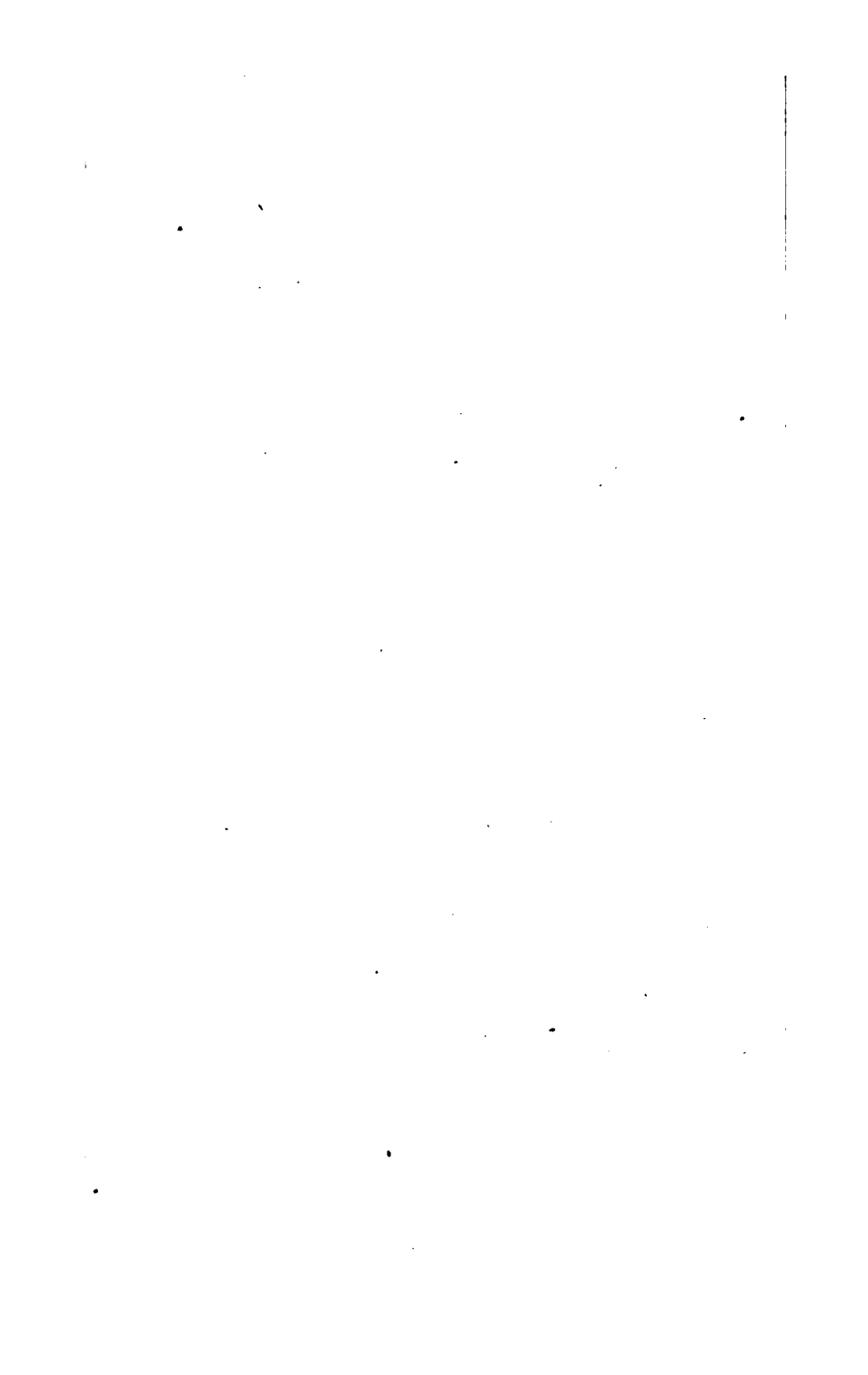


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TO

HENRY CLUTTERBUCK, M.D.

MEMBER OF THE ROYAL COLLEGE OF PHYSICIANS;
LECTURER ON THE THEORY AND PRACTICE OF PHYSIC,
MATERIA MEDICA, AND CHEMISTRY;

This Work,

ENTITLED

"THE FIRST LINES OF CHEMISTRY,"

IS MOST RESPECTFULLY DEDICATED,

BY HIS OBEDIENT AND VERY HUMBLE SERVANT,

THE AUTHOR.

London, May, 1828.

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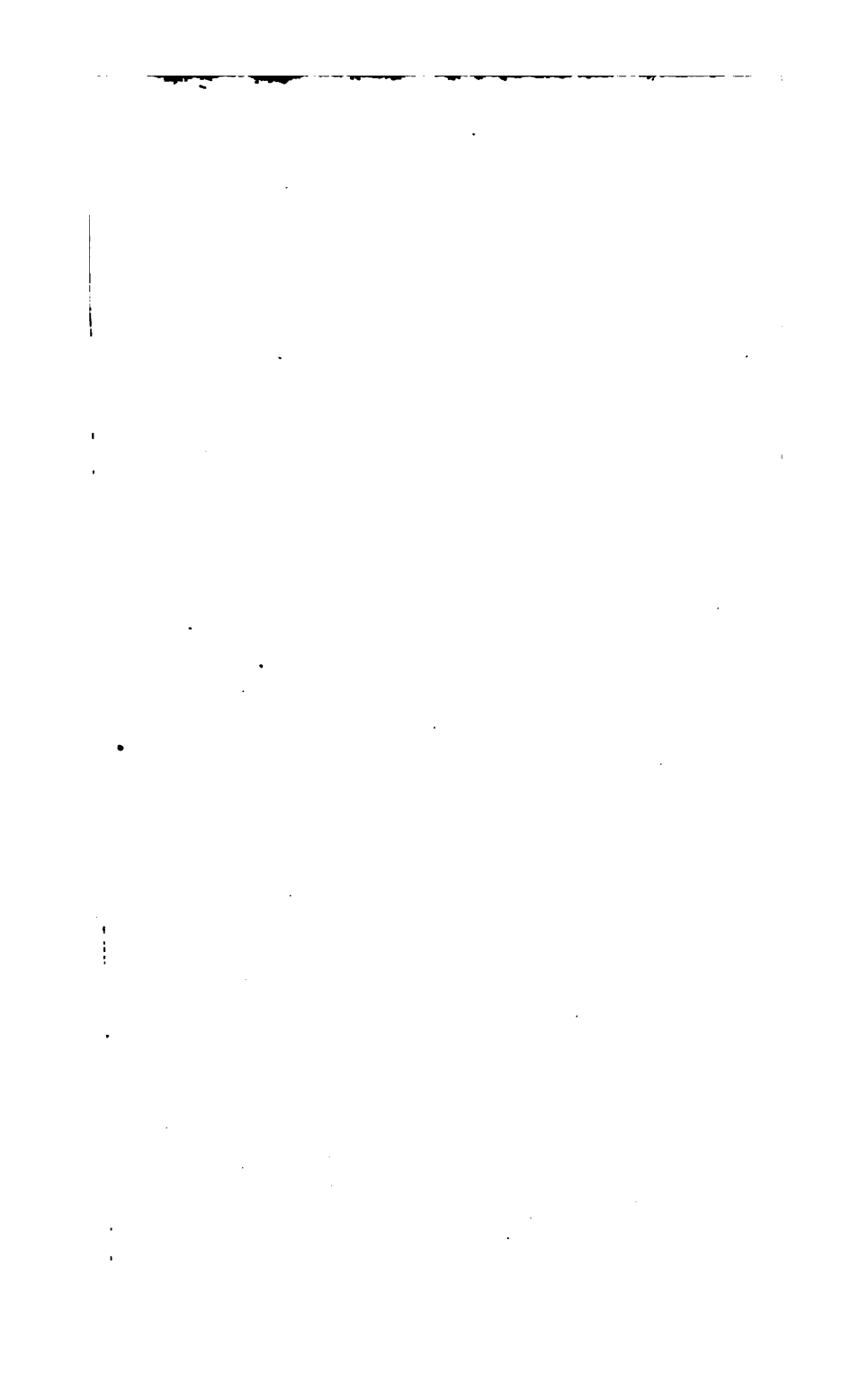
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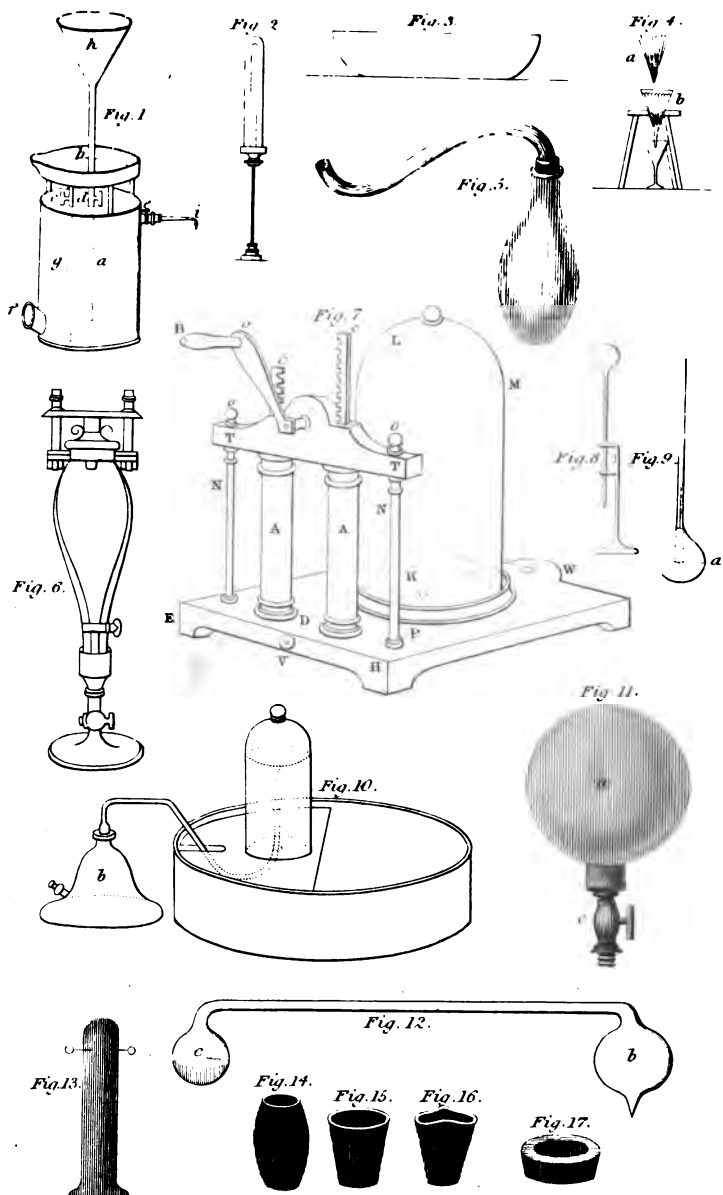
 ERRATA.

Page 98, note 2d, line 2d, for *effect* read *affect*.

Page 108, in the paragraph '*Sulphate of Magnesia*,' last line but two, for *or* read *on*.

Page 156, first line, for *Lombac* read *Tombac*.





EXPLANATION OF THE PLATES.

PLATE I.

Figure 1.—A glass measure graduated into certain capacities, either by weight or bulk, to a standard fluid.

Note. The weights and measures required by the chemist are few and simple, but they should be accurate, and their relative values well defined. See *Table of Weights and Measures*, p. 297.

Fig. 2.—The balance, a pair of scales—an instrument sufficiently known—serves to ascertain the equality of the absolute or difference of weight of bodies.

Note. The beam of a good balance should remain in equilibrium without the scales, and when the scales are changed, and should be very sensibly affected with a small portion of additional weight when loaded. They should hang in a dry place, and in a good light. The most delicate scales should be kept in glass cases, and should not be taken out without occasion.

Fig. 3.—Mortar and pestle. (A small glass mortar.)

Note. Pounding is one of the most common operations of the laboratory; the chemist, therefore, must be provided with mortars of different kinds—glass, wood, iron, marble, siliceous stones, and porcelain.

Fig. 4.—Retort. Retorts are made for various processes, in the arts, of different metals; but those in common use are chiefly of glass and earthen-ware. They are either plain or tubulated. The plain have no other opening beside that at the end of the tube. The tubulated have an opening at the curved part, supplied with a stopper for the convenience of charging them.

Note. Glass retorts require some management and care to prevent them from breaking: if any solid substance be put into a retort, which adheres to the bottom of it when over a lamp, it is almost sure to break; if a retort be laid down while hot upon a substance capable of conducting away the heat from it rather suddenly, it is almost certain of breaking; but it may be laid down with safety on a piece of woollen cloth, or on dry glass.

Fig. 5.—Receiver. Receivers are of various kinds and constructions. As air jars, in the pneumatic trough, for collecting, trans-

XVIII EXPLANATION OF THE PLATES.

ferring, and preserving gases. Bell glasses (Fig. 14), and balloons are used for the same purposes.

Fig. 6.—A *Matrass* is a glass vessel, used for making solutions. It is generally of a spherical form, flattened slightly at bottom, and resembles the Bolt-head. (See *fig. 12.*)

Fig. 7.—*Cucurbit*. A wide-mouthed flask of the figure of a gourd, used for various chemical purposes. It is also called a body.

Figs. 8 and 9.—*Spirit lamps*. For chemical experiments upon a small scale, these are by far the most convenient lamps, as the flame of spirit of wine does not blacken, or in any degree soil the vessel to which it is applied. The degree of heat may also be regulated by raising the wick higher up, or by drawing it lower down.

Note. Any short, small glass bottle, may be made to answer for a spirit lamp, but the shape represented in the plate are those generally used; and in order to prevent waste of the spirit by evaporation, the lamp requires to have a glass cap fitted to it by grinding, so as to enclose the wick in air-tight.

Fig. 10.—*Syphon*.—An instrument sometimes requisite in the laboratory, for drawing fluids out of vessels that do not admit of being moved. There are different forms of this instrument.

Fig. 11.—The common funnel, which requires no description.

Note. The chemical laboratory should be provided with funnels of glass, brown stone-ware, porcelain, and tinned iron, of different bores and diameters.

Fig. 12.—*Bolt-head*. A name given to a spherical glass vessel, flattened a little at the bottom, and provided with a long slender wick, chiefly used for making solutions, and for processes of sublimation. See *Matrass, fig. 6.*

Fig. 13.—*Bladder with stop-cock*.

Note. A large bladder mounted with a stop-cock is very convenient for throwing up soap bubbles filled with hydrogen, or a mixture of oxygen and hydrogen gas. (See Experiments with the Gases, and other occasional purposes.)

Fig. 14.—*Bell glass with a stop-cock*. Bell glasses of this kind are convenient for transferring gases into exhausted vessels, bladders, &c.

PLATE II.

Fig. 1.—*Pepy's improved oxygen gas holder*.

Note. This convenient apparatus consists of a japanned iron or copper vessel; *a* is the part which contains gas, and is usually made capable of holding from six to eight gallons: *b* is a cistern for holding water, having two tubes opening in it. These tubes supplied with stop-cocks are seen at *c* and *d* underneath the

cistern, the middle one *d* is continued nearly to the bottom of the vessel; the other one *c* opens into the lower vessel *a*, but is not continued downwards.

To fill this vessel with water, the aperture is closed with its screw, the stop-cocks *c*, *d*, *e*, being all open; water is poured into the cistern above (the funnel and tube which unscrew at the bottom of the cistern being removed), and it descends through the tubes and stop-cocks *c* and *d*, and forces the air out at *e*; when the gas holder is nearly full, the stop-cock *e* must be closed, and what remains of air will find its way out through *c*, until the vessel is full; the stop-cock must then be closed.

To fill this vessel with oxygen gas, an iron bottle containing black oxide of manganese is put into the fire; and a communication being made between the bottle and the gas holder by a metallic tube, which is introduced at the aperture *f*, as soon as the iron bottle attains the temperature of *e*, red heat gas comes over, and ascending through the water, occupies the upper part; the water descending and flowing out at the aperture as the gas goes in.

The tube *g* is of glass, and has a communication at top and bottom of the gas holder, and shews the progress of its filling and the quantity of gas which it contains at any time. When the vessel is sufficiently filled, the aperture *f* must be closed effectually. The gas will then be ready for use.

If the gas is to be transferred into a bladder, a connecting piece must be screwed in at *e*, and the bladder, previously furnished with a stop-cock, is screwed to the connecting piece; the cistern must then be filled with water, and the stop-cock *d* and *e* opened; the water will descend to the tube *d*, compress the gas, and cause it to issue at *e* into the bladder; when the stop-cocks are closed, the bladder may be withdrawn.

To transfer gas into a bottle or jar, the vessel which is to receive the gas must be filled with water, and its mouth placed downwards, over the hole above the stop-cock *c*; this stop-cock must be opened, and also the stop-cock at *d*; the water will then descend by the long tube in the centre *d*, compress the air, and cause it to ascend through *c* in the bottle or jar, which must be held a very little on one side, that the water may be able to descend out of the bottle uninterrupted by the close contact of the mouth of the bottle and the bottom of the cistern. When the bottle is full, and the stop-cocks closed, it may be removed by introducing a cork under water; the bottle may then be turned with its mouth upwards. When a jar which is open at the bottom is filled, it may be removed by slipping a hollow dish under the open part, below the surface of the water; the gas will be prevented from escaping by the water in the shallow dish, that rises a little way above the jar or receiver.

It will be remembered that, during all the operations here described, the funnel and long tube are removed by unscrewing it at

the bottom of the cistern; the use of this part of the apparatus is now to be described. By screwing it on as represented in the figure, and also the jet pipe *c*, the apparatus is converted into an excellent hydraulic blow-pipe, while it is kept full of water to the top of the funnel *h*. When filled with oxygen gas, it is capable of producing a very intense heat.

. This gasholder is chiefly used for oxygen and hydrogen; and occasionally for other gases.

Fig. 2.—A condensing syringe. This consists of a common syringe, about six inches long, and three-fourths of an inch in the bore. At the lower extremity of the piston is a cavity which receives the substance intended to be fired.

Note. A considerable part of the caloric, which exists in gas in a latent state, may be rendered sensible by rapid mechanical compression: *e. g.* If air be suddenly compressed in the pall of an air-gun, the quantity of caloric liberated by the first stroke of the piston, is sufficient to set fire to a piece of tinder called *amadou*. A flash of light is also perceptible at the moment of condensation. This fact has been applied to the construction of a portable instrument for lighting a candle.

Fig. 3.—An evaporating bason.

Note. Evaporation is used for separating volatile fluids from those which are fixed in the same degrees of heat; and it is further promoted by using shallow vessels, and extending the surface of the fluid as much as possible. See p. 43.

Fig. 4.—A Filtering stand and bag. This consists of three legs supporting an horizontal board, furnished with a hole, for supporting a funnel.

Note. Filtration is a finer species of sifting. It is sifting through the pores of paper, flannel, fine linen, sand, pounded glass, porous stones, or the like; but it is used only for separating fluids from solids, or such parts as may happen to be mechanically suspended in them, or not chemically combined with the fluid—*e. g.*, salt water cannot be deprived of its salt by this process; but muddy water may be rendered pure and clean by it.

Fig. 5.—Bottle with recurved tube fitted by grinding.

Note. This bottle is useful for the production of gases; they are commodious when the evolution of the elastic fluid is not rapid, and the quantity demanded only moderately small. Bottles of this kind are sometimes tubulated.

Fig. 6.—Cavendish's apparatus for the composition of water. It is composed of a very thick vessel *a*, with a glass stop-cock *b*, and a ground glass stopper *c*, which has two platinum wires *d* passing through it into the inside of the vessel. There is also a collar of brass round the neck of the thick glass vessel, with two brass rods passing through it, for the purpose of receiving a bar of the same metal, the intention of which is to keep down the stopper, when gases are exploded in the inside. The bar is se-

cared upon the end of each rod, and a brass cap *e* receives the lower part of the glass vessel, which is firmly fixed into it with cement : *f* is a brass stop cock, which admits of being unscrewed at the brass cap above or at the brass foot below. For the use of this vessel, see *Philosoph. Trans.*

Fig. 7.—The PNEUMATIC or AIR PUMP.—This is one of the most useful of all philosophical instruments, the actions of which depend on the mechanical properties of the air. By the help of this machine the physical properties of air may be demonstrated in the most simple and elegant manner. Its construction is as follows:—

EG is a square table of wood : *AA* are two strong barrels or tubes of brass, firmly retained in their position by the piece of wood *TT*, which is pressed on them by screws *OO*, fixed on the tops of the brass pillars *NN*. These barrels communicate with a cavity in the lower part or bed of *D*. At the bottom within each barrel is fixed a valve, opening upwards, and in each a piston works, having a valve likewise opening upwards. The pistons are moved by a cog-wheel in the piece *TT*, turning by the handle *B*, and whose teeth catch in the racks of the pistons *CC*. *P* is a circular brass plate, ground perfectly smooth, having near its centre the orifice *K* of a concealed pipe, that communicates with the cavity ; in the piece or bed of the pump, *D* at *V*, is a screw that closes the orifice of another pipe, for the purpose of admitting the external air when required. *LM* is a glass receiver, out of which the air is to be exhausted. It is placed on the brass plate *F*, slightly greased to prevent the air from insinuating itself under the edge of the glass receiver.

When the handle *B* is turned, one of the pistons in the barrel *A* is raised and the other depressed ; a void space is consequently left between the raised piston and the lower valve in the correspondent barrel ; the air contained in the glass receiver *LM*, communicating with the barrel by the orifice *K* on the ground brass plate, immediately raises the lower valve by its spring, and expands into the void space ; and thus a part of the air in the receiver is extracted. The handle then being turned the contrary way, raises the other pistons, and performs the same act in its correspondent barrel ; while, in the meantime, the first-mentioned piston being depressed, the air by its elasticity closes the lower valve, and raising the valve in the piston makes its escape. The motion of the handle being reversed, the first barrel again exhausts while the second discharges the air in its turn ; and thus, during the time the pump is worked, one barrel exhausts the air from the receiver, while the other discharges it through the valve in its piston.

Hence it is evident that the vacuum in the receiver of the air-pump can never be perfect,—that is the air can never be entirely exhausted : for it is the spring of the air in the receiver that raises

the valve, and forces air into the barrel, and the barrel at each exhaustion can only take away a certain part of the remaining air, which is in proportion to the quantity before the stroke, as the capacity of the barrel is to that of the barrel and receiver added into one sum. This, however, is an imperfection seldom, if ever, of any consequence in practice.

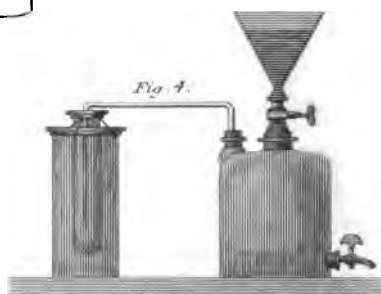
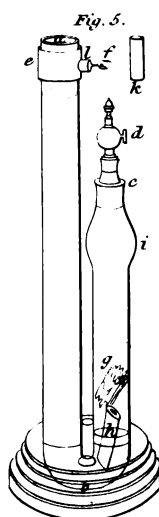
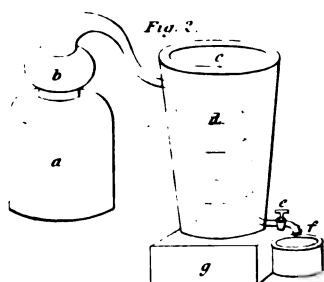
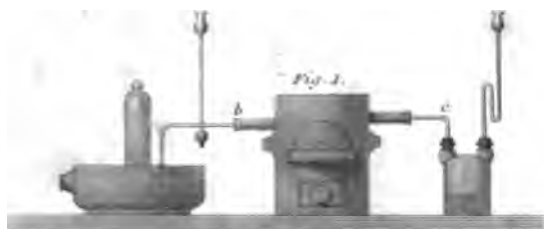
Figs. 8, 9.—AIR THERMOMETER FOR LIQUIDS.—An instrument intended for the purpose of ascertaining the temperature of liquids. It consists of a bottle *a*, partly filled with any coloured liquid, and partly with air, a glass tube of small bore, open at both ends, being either cemented or hermetically sealed in the bottle, so that its lower extremities may nearly touch the bottom of the bottle. The expansion of the included air, on the application of heat, drives the coloured liquid up the tube.

Fig. 10.—PNEUMATIC TROUGH OR CISTERN. (See *fig. 7, pl. iii.*) The discovery of gaseous fluids, in modern chemistry, gave rise to the necessity of some peculiar instruments, by means of which those substances may be caught, collected, and properly managed.

Fig. 11.—GAS BOTTLE.—When gas is extricated, in consequence of chemical action, with the application only of a moderate heat, the glass flask or bottle with recurved tube (see *fig. 5, pl. ii.*) is used. All these kind of bottles should be blown very thin at bottom, that they may support the heat of a spirit lamp suddenly without cracking. In this figure (*fig. 2.*) the tube, which is curved nearly in the form of the letter *z*, is fitted into the neck by grinding.

Fig. 12.—CRYOPHORUS.—A name given by Dr. Wollaston to this instrument. It consists of a glass tube, about ten or twelve inches long, having an internal diameter of about one-eighth of an inch, terminated at each extremity by a hollow ball, *b c*, one inch in diameter; one of these balls contains about half an ounce of water, and the other is as perfect a vacuum as can possibly be obtained by the glass-blower in the construction of the instrument. If the empty ball *b* be kept immersed in a mixture of snow and muriate of lime, or any other freezing mixture, the water in the ball *c* will be frozen in a very short time; and this effect takes place, though the ball *c* be two or three feet distance from the empty ball *b*.

Fig. 13.—DETONATING TUBE.—It is frequently an interesting object to pass the electric spark through the different kinds of air, either alone or mixed together. In this case a metallic wire is fastened in the upper end of a thick glass tube hermetically sealed at one end, the sides of which, at about the distance of two inches from the sealed end, are perforated with small holes, in which wires are fixed by cement, the extremities of which, within the tube, are distant one quarter of an inch. It is made wider at the bottom to stand more steady. This instrument being filled with water or quicksilver, and inverted, a quantity of the gases intended to



be submitted to the electric spark is introduced so as to depress the fluid one inch or more beneath the wires. The electric spark is made to pass from the one wire to the other, by connecting one of them with the conductor of the common electrical machine, and hanging a chain on the other.

Note. A tube of this kind, when graduated into equal parts, forms Volta's Endiometer.

Figs. 14, 15, 16, 17.—**CRUCIBLES.**—Vessels for the purpose of exposing solid substances to intense heat for the purpose of fusing them, or to favour their mutual chemical action. They are usually of the form of a short truncated inverted cone; some are triangular.

Note. A crucible ingot to support the strongest heat without melting, as well as resist the attacks of all agents exposed to heat in it. The Hessian crucibles are composed of clay and sand. Wedgewood's, of porcelain clay, are the best for experiments in the small way. There are also silver, platina, and iron crucibles, and for various purposes, in proportion to the action of the substance, or the heat they are required to resist.

PLATE III.

Fig. 1.—**GUN-BARREL APPARATUS.**—A name given to a gun-barrel when combined with a furnace. The one in this instance is intended for a fluid or gas to pass through an ignited gun-barrel; for instance, suppose it is wished to pass carbonic acid through the tube—make a gun-barrel *b* pass through a furnace, taking care to incline it at the narrowest part; adjust to one of its extremities a bent tube, and let the other extremity of the barrel terminate in a tube *c*, combined with a tube of safety. Introduce one extremity of the tube, as shewn in the design, under a bell in the pneumatic basin. When the apparatus is thus disposed and well luted, bring the gun-barrel to a red heat, and when thoroughly red-hot, pour diluted muriatic acid into the hydrostatic funnel, fixed into the two-necked bottle, drop by drop, to disengage the carbonic acid from marble or chalk put into the two-necked bottle for that purpose.

Fig. 2.—**METALLIC STILL.**—This is the most usual form of a metallic still; the body or boiler of the still *a*, and the head or capital *b*, are made of copper; the worm tub *c* is of wood, and the worm *d* of any convenient metal. The liquid which is to be converted into vapour is put into *a*, and made to boil by the application of heat; before the capital *b* becomes hot, a portion of the vapour will be condensed by the cold of its sides, but it is soon too much heated to condense the vapour; it then passes over into the refrigeratory or worm *d*, which is cooled by a quantity of cold water in the tube; this water receiving the heat which is set

XXVI EXPLANATION OF THE PLATES.

Fig. 7.—PNEUMATIC TROUGH OR CISTERN.—When this apparatus is used (see also *fig. 10. pl. II.*) the trough or vessel, (wooden or metallic) is to be filled with water to such an height as to rise about one inch above the upper surface of the shelf; *a* is a glass jar inverted with its mouth downwards, which rests upon the shelf. If this or any other vessels open only at one end, be plunged under water, and are inverted after they are filled, they will remain full, notwithstanding their being raised out of the water, provided their mouths be kept immersed; for in this case the water is sustained by the pressure of the atmosphere in the same manner as the mercury in the barometer.

* * * *The use of chemical apparatus of every description is only to be sufficiently understood by keeping them substantially, and in actual practice; though the ideas here conveyed of them, by accurate drawings and illustrations, will prepare the student for an early and correct material acquaintance with them.*

INTRODUCTION.

THE multifarious and rapid improvements in the arts and manufactures, by the judicious application of the principles of Chemistry, have unquestionably rendered a knowledge of this science indispensable to almost every class of society. So well satisfied, indeed, are the better informed people of every country, at the present day, of its general utility and importance, that it has now become an essential constituent of a liberal education: nor ought this to excite our surprise, when it is considered that the science of chemistry has for objects every substance of the material world. Hence the benefits to be derived from it are sufficiently obvious to require much illustration; whilst the many disadvantages under which those must labour who are unacquainted with chemistry, are incalculable.

The medical practitioner, if he be not a chemist, will have not only to depend upon the knowledge of others, but he will have to endure the mortifying degradation of being compelled to submit to many painful and perplexing disappointments, as well as to witness many un-

expected results from the effects of medicine, in the administration of two or more powerful remedies in conjunction, without being able to comprehend them; but with a knowledge simply of the "First Lines of Chemistry," he would have understood that many of the formulæ of the Pharmacopœia, which are salutary and efficacious, may be rendered both inert and destructive, if mixed with incompatible substances. The study, therefore, of the chemical affinities, which subsist among the various articles of which the Materia Medica is composed, is too vitally important to be dispensed with by the medical student. It is by this means we are more readily acquainted with the effects which certain causes chemically produce in the animal economy—a laboratory in which the varied functions of secretion, absorption, sanguification, composition, decomposition, &c., are continually in operation; and where the nature of every inspiration we make, and every pulsation that takes place within us, requires the acuteness of a profound chemist to perceive and comprehend. And without a sufficient knowledge of chemistry, how would it be possible for the physician to understand the nature of the animal, vegetable, mineral and ærial poisons,—many of which, even in the present state of chemical knowledge, are but imperfectly known to the most erudite professors?

But it is not to the medical profession alone

that Chemistry is subservient—it belongs to the arts generally. And as regards the manufactures, there is scarcely one of any consequence that does not, in some measure or other, depend upon chemistry for its perfection, establishment, and success.

To the agriculturist, Chemistry is of the first consideration; and, although it is not to be expected that every husbandman should be a profound chemist, we may venture to say that every gentleman who wishes to improve his estate, and to advance the art of agriculture, ought to be well versed, at least, in the principles of philosophical chemistry, without which he can neither conduct experiments properly, nor explain satisfactorily the several phenomena resulting from them.

The uses to which chemistry may be applied in agriculture are acknowledged to be important and extensive, but our present limits will only permit us briefly to mention a few of them.

To the science of Chemistry it belongs to distinguish the various kinds of earth that may be rendered more prosperous and productive, according to their natures and proportions;—to determine which of them is the fittest for particular purposes; to ascertain the different qualities of the various sorts of manure, and to point out proper methods of applying them; to discover the best method of improving a barren soil; to effect, by a suitable mixture of earths, what is not to be accomplished by manual labour

alone. It also appertains to Chemistry to suggest suitable means for preserving grain from smut, blights, or mildews; also for destroying or driving away insects, reptiles, and other noxious vermin, which usually prey on fruits, seeds, or vegetables. To be brief: when the products of agriculture are even obtained, the aid of chemistry is still essentially necessary towards their preservation, and the means of fitting them for the various purposes to which they are destined.

Grain and farinaceous vegetables are convertible into flour, bread, starch, malt, &c. In proportion to the saccharine matter contained in them, they become subjects of the vinous and acetous fermentation; and hence, the operations of baking, brewing, the making of wine, cider, vinegar, &c., are so many chemical processes, which, for the want of the requisite stock of knowledge, in many cases will either fail altogether, or are carried on with comparatively little advantage.

The preparations of flax and hemp for sundry uses, and the operation of bleaching and whitening linen; also of preserving wood from putrefaction, and preparing other vegetable productions for various economical purposes, depend all upon chemical principles.

The productions of the animal kingdom afford a variety of raw materials which enrich the farmer, and which, by suitable management, constitute no inconsiderable share of the national wealth. For instance,—meat, eggs, milk,

butter, cheese, honey, wax, tallow, hides, &c.; all these, by chemical aid, may be preserved in a sound state for a considerable length of time; or be even sometimes restored, in a great measure, after corruption has begun to take place. They may be also further improved, and converted to a variety of economical uses to the highest advantage, if their chemical properties be properly understood.

In iron, one of our staple commodities, it will be observed, that from the smelting of the ore to its conversion into steel, every operation is the effect of chemical affinity; a knowledge of which cannot be too sedulously studied. Indeed, in a scientific point of view, it requires no small share of chemical knowledge to appreciate the value of the different ores; and to construct such apparatus for their reduction as may be best adapted to facilitate their fusion, and for the production of good pigs. The processes which follow, in order to convert the metal into malleable iron, are wholly dependent on chemical principles, and will be conducted to the best advantage only by those who have acquired a knowledge of the chemical changes which are effected by these operations. The manufacturers of cast iron utensils, called iron founders, are also indebted to chemistry for much valuable information. It teaches them how to mix the different kinds of metals—to apportion carbonaceous and calcareous earth, and to reduce the old metal which they receive in exchange.

The manufacturers of woollen, cotton, and calico, also cotton printing and dyeing, of so great importance both at home and abroad, are much indebted to chemistry; because, in order to preserve these sources of national wealth, the utmost attention must be paid to the beauty, variety, and durability of the texture and colours; in the management of which every process is chemical, and not a colour can be imparted but in consequence of the affinity which subsists between the cloth and the dye, or the dye and the mordant which is employed as a bond of union between them.

Bleaching, so intimately connected with calico printing, has received such decided improvement from chemistry, that no man is now capable of conducting it to the best advantage without a proper knowledge of the principles on which the present practice of the art is established.

The manufacturers of earthenware and porcelain, so much improved and extended by the industrious Wedgewood, and which affords employment to thousands, are all dependent on chemistry for their successful management.

The manufacture of glass is also entirely performed by Chemistry, consisting in the fusion of siliceous earth with alkali and the oxides of lead.

Tanning of hides, a process formerly carried on by persons who merely following a set of prescribed operations to which they had been accustomed, without knowing the real cause of any of the changes produced, is now, however,

well ascertained to consist in impregnating the animal matter with that peculiar vegetable principle called *tan* (or *tannin*), the effect of which may altogether be explained on chemical principles.

The manufacturers of *Morocco leather*, an article comparatively new in the productions of this country, have the utmost reason to regret the want of chemical knowledge; for, until within these twenty or thirty years, the consumers of Morocco depended entirely on foreign supply; many fruitless attempts having been made to prepare an adequate article of the same kind in this country.

The manufacture of soap and candles would save many thousands annually, were these trades carried on more scientifically. Make a soap-boiler a good chemist, and you teach him how to analyze barilla, kelp, potass, &c., so as to ascertain the proportion of alkali in each; the only sure guide to purchasing with advantage and profit, which with the common manufactures is mere chance. And foreign tallows, which frequently contain a large portion of sebacic acid, rendering them inferior to the English, may be purified, at the most trifling expence, by chemical means; and by the proper application of chemical agents, other brown tallows may be rendered beautifully white, and fit for the best purposes.

Brewing is altogether a chemical process. The distiller and the sugar-baker also will receive benefit from a knowledge of chemistry.

The refining of gold and silver, is in like manner attributable to the play of chemical affinities. In short, the various operations of nature, and the changes which take place in the several substances around, are so much the better understood by attention to the laws of chemistry, that in every walk of life the chemist will ever have a manifest advantage over his illiterate neighbour.

Knowledge, says the illustrious Verulam, is incomplete, and scarcely deserves the name, unless it enables us to explain its several phenomena. Is it not then surprising, considering the rapid progress which chemical science has been making for some years past, that it was not till very lately that its professors pointed out its application to the improvement of agriculture and rural economy, as well as to the philosophical commerce of the arts.

The ancient chemists were fond of inventing abstruse terms, and frequent in the use of them; at present, however, this is pretty generally and very justly exploded. The chemistry of the present enlightened period, is indebted for its nomenclature to Lavoisier, Berthollet, Gayton-Morveau and Fourcroy; and the principles which guided them in its construction, are extremely simple and ingenious. The known elementary substances, and the more familiar compound ones, were allowed to retain the appellations which general usage had assigned to them. The newly discovered elements were named

from some striking property. For example,—it was supposed that acidity was owing to the presence of the vital air discovered by Priestley and Scheele; they gave it the name of oxygen, derived from two Greek words, signifying *generator of acid*; and they called inflammable air hydrogen, from the circumstance of its entering into the composition of water.

The advantage of a nomenclature which arranges the different parts of a science in so systematic a manner, and which gives such powerful assistance to the memory, is incalculable; indeed, it is almost needless here to repeat, or in the present state of knowledge, to urge the necessity of a method; in all studies, it is the very soul of science; and all attempts toward the acquisition of knowledge, without it, must end in uncertainty and confusion.

From the preceding observations, it necessarily appears, that both in public and private manufactories, and various articles of rural economy, a multitude of operations are continually going on, which undoubtedly depend on chemical principles. It seems evident, that no material change can be wrought in bodies, but either by separating something from them, or combining something with them: but it is by chemical attraction, that both separation and combination are performed; consequently it is from an accurate knowledge of chemical laws, that the clearest lights, and ablest assistances, are

to be obtained. In fine, chemical research conducts to the knowledge of philosophical truth, and forms the mind to philosophical enlargement and accuracy of thought, more happily than any other species of investigation in which the human intellect can be employed.

THE
FIRST LINES
OF
PHILOSOPHICAL AND PRACTICAL
CHEMISTRY.

CHAPTER I.

MATERIAL SUBSTANCES.

Question. WITH what properties are material substances endowed ?

Answer. Material substances are endowed with two kinds of properties—namely, physical and chemical ; and the study of the phenomena resulting from these properties has given rise to two corresponding branches of knowledge.

Q. What are these branches of knowledge ?

A. Natural philosophy and chemistry.

Q. Describe the physical properties of material substances ?

A. The physical properties of material substances are either general or secondary. The first, or general, are so called because they are common to all bodies ; the latter, or secondary properties, are thus named from being observable in some bodies only. Among the first are commonly ranked extension, impenetrability, mobility, extreme divisibility, gravitation, and porosity.

Q. How are extension and impenetrability defined?

A. Extension is the property of occupying a certain portion of space: *e. g.*, a substance is said to be extended when it possesses length, breadth, and thickness. By impenetrability is meant that no two portions of matter can occupy the same space at the same moment of time.

Obs.—Every thing that possesses extension and impenetrability is matter, which, though susceptible of motion, has no power either to move itself, or arrest its progress when an impulse is once communicated to it.* Matter is divisible to an extreme degree of minuteness. A grain of gold may be beaten out into so fine a leaf as to cover fifty square inches of surface, and contain two millions of visible points; and yet the gold which covers the silver wire, used in making gold lace, is spread over a surface twelve times as great.—*Nicholson's Introduction to Nat. Philos.*

Q. What is meant by gravity, or the gravitation of bodies?

A. Gravity, or gravitation, is that power which causes all bodies to descend in straight lines towards the centre of the earth, when left at liberty, at a distance from its surface. This power is also called the attraction of gravitation, or terrestrial attraction; and the force required to separate a body from the surface of the earth, or prevent it from descending towards it, is called its weight.

Obs.—Every particle of matter is equally affected by gravity; the weight, therefore, of any body will be proportional to the number of ponderable particles which it contains.

*. This indifference to rest or motion has been expressed by the term *vis inertiae*, as if it depended on some specific force resident in matter; but it may with greater propriety be regarded as a negative character, whereby matter is entirely given up to the operation of the various forces constantly acting upon it.

Q. What do you mean by porosity ?

A. The minute particles of which bodies consist, are disposed in such a manner as to leave certain intervals or spaces between them ; and this is called *porosity*.

Obs.—These interstices can sometimes be seen by the naked eye, and frequently by the aid of glasses ; but supposing they were wholly invisible, it would still be certain that they exist. All substances, even the most compact, may be diminished in bulk, either by mechanical force, or by reducing its temperature. Hence it follows, that their particles must touch each other only, if at all, at a very few points ; for if their contact was so perfect as to leave no interstitial spaces, then would it be impossible to diminish the dimensions of a body, because matter would be incompressible, and could not yield.

Q. What are the secondary properties of matter ?

A. The secondary properties of matter are opacity, transparency, softness, hardness, elasticity, colour, density, solidity, fluidity, &c.

Obs.—The condition of bodies, as regards several of these secondary properties, seems dependant on the operation of two opposite forces, cohesion and repulsion. To understand how the particles of a body can attach themselves to one another and form a whole, they must be supposed to possess a power of reciprocal attraction. This force is called cohesion, cohesive attraction, or the attraction of aggregation.

Q. What is the difference between gravity and cohesion ?

A. Gravity is exerted between different masses of matter, and acts at sensible and frequently at very great distances ; while cohesion exerts its influence only at insensible and infinitely small distances. It enables similar molecules to cohere,

and tends to keep them in that condition. This is best exemplified by the resistance which a hard body, as iron or marble, affords to being broken by any external force.

Q. Is matter subject to any other kind of attraction ?

A. Yes; to one, different from those yet mentioned, termed chemical attraction or affinity; which, like cohesion, acts only at insensible distances, and thus differs entirely from gravity.

Q. How is chemical attraction distinguished from cohesion ?

A. Chemical attraction is distinguished from cohesion by being exerted between dissimilar particles only, while the attraction of cohesion unites similar particles :

Ex.—A piece of marble is an aggregate of smaller portions of marble attached to one another by cohesion, and the parts thus attached are called integrant particles; each of which, however minute, is as perfect marble as the mass itself. But the integrant particles consist of two substances, lime and carbonic acid, which are different from one another, as well as from marble, and are united by chemical attraction. They are the component or constituent parts of marble. The integrant particles of a body, therefore, are aggregated by cohesion; the component parts are united by affinity.

CHAPTER II.

CHEMISTRY.

Q. How is Chemistry defined?

A. Chemistry is that science, by which we are enabled to detect the peculiar properties of all natural bodies, whether in a simple or compound state.

Obs.—The following definitions of Chemistry have been given by some of the best writers:

“Chemistry is a science, by which we become acquainted with the intimate and reciprocal action of all the bodies in nature upon each other.”—*Fourcroy*.

“Chemistry is the study of the effects of heat and mixture, with a view of discovering their general and subordinate laws, and of improving the useful arts.”—*Dr. Black's Lect.* vol. i. p. 12.

“Chemistry is that science which treats of those events or changes in natural bodies which are not accompanied by *sensible* motions.”—*Dr. Thompson*.

Q. How are the properties of bodies chemically examined?

A. The chemical examination of bodies is, usually effected by producing a change in the nature or state of the body to be examined.

Exp.—If a little powdered chalk (carbonate of lime) be put into a glass of water, the chalk will sink to the bottom of the vessel. No chemical action has hitherto taken place; the water and the chalk, therefore, remain unaltered. But if a few drops of diluted sulphuric acid be added to the mixture, a violent effervescence will take place. A chemical union of the

two substances will be the result; the identity of each substance will be destroyed; and a sulphate of lime, a body entirely different from any of those employed, will be produced.

Q. How is a change effected in the qualities or states of natural bodies?

A. By means of heat, which has a tendency to separate the particles of all bodies from each other; or, by the mixture of some other matter with that intended to be changed.

Exp.—Put, for instance, a small piece of solid camphor into a phial half filled with diluted alcohol; in a short time the camphor will be dissolved, and the spirit will be as transparent as at first. If water be now added, it will combine with the ardent spirit, and the camphor will be precipitated. The solution of the camphor in the alcohol is owing to the affinity which exists between these two bodies, and their dissolution by the addition of water is the consequence of the greater affinity of the water for the alcohol than for the camphor. In this manner the camphor, after its solution with the alcohol, may be nearly all recovered as at first; and by distillation, the alcohol may be separated from the water, and exhibited in a separate state.

Q. In what manner does the application of heat and mixture enable us to examine the properties of bodies?

A. By heat and mixture the decomposition of a compound body is effected.

Obs.—This is also termed analysis, which is distinguished into the *simple* and the *complicated*. The first is effected whenever a body is so decomposed as to enable us to exhibit its elements or component parts in a separate state, and to reproduce that body by the re-union of these elements. The second, or *complicated* analysis, occurs where the elements of a body form new compounds during its decomposition, and which cannot be reunited to reproduce a similar substance to that which has been thus operated upon.

Q. Are there any other means resorted to for

the purpose of ascertaining the exact nature of bodies?

A. Yes. In order to ascertain the exact nature of bodies, chemists have often recourse to *synthesis* as well as analysis.

Obs.—Whenever the component parts of any body are reunited in order to form a similar substance, and a similar substance is actually produced, the nature of that body is said to be proved by *synthesis*. When a body admits of being proved both by *synthesis* and analysis, the result is as satisfactory as can be desired.

Q. Explain the meaning of chemical decomposition?

A. Chemical decomposition is the act of dividing a body into its simple elements: *e. g.*, water may be decomposed, and reduced into oxygen and hydrogen, which are simple substances, incapable of further decomposition.

Exp.—Take Epsom salt (sulphate of magnesia), dissolve it in boiling water, and pour into this mixture a little of a solution of carbonate of soda—the soda will throw down a white powder, which, on examination, will be found to be carbonate of magnesia. When settled, decant the supernatant liquor, evaporate it till a pellicle rises on its surface, and set it aside to crystallize. When cold, crystals of sulphate of soda, (Glauber's salt) will be found in the vessel. In this process, or decomposition, the sulphuric acid of the Epsom salt combines with the soda to form sulphate of soda, and the carbonic acid of the soda combines with the magnesia to form carbonate of magnesia. In this manner Epsom salt may be analysed, and shown to consist of sulphuric acid and magnesia. And by *synthesis*, in order to prove the composition of Epsom salt, dissolve magnesia in diluted sulphuric acid, saturate the liquor and crystallize—Epsom salt will be the result.

Obs.—Chemists, it may be added, have not only the power of decomposing natural bodies, but of producing, by

certain combinations, various other substances, such as are not found in the kingdom of nature. Alcohol and ether are both of this class.

Q. What are the different states of natural bodies?

A. All natural bodies are either solid, liquid, or æriform.

1. Solidity consists in that quality of bodies whereby their parts firmly cohere, so as to resist impression.

2. Liquid substances are those whose parts do not firmly cohere, but readily yield to any impression, and have free motion among themselves.

3. Æriform bodies are those in the state of air, gas, or vapour.

Obs.—The difference in these bodies is nothing more than that solids are converted into liquids by heat, a certain increase of which would convert the liquids into vapour. Liquids are also called fluids: *e. g.*, the air is called a fluid, because it flows as a fluid, because like a fluid it presses in every direction, and because light substances will float or swim in it: for according to an established law of nature, all substances will swim in fluids, if such substances be specifically lighter than the fluid they swim in. For instance, a piece of cork swims upon water, whilst a stone sinks in it—that is, the first swims because it is *lighter*, and the other sinks, because it is *heavier* than water; not that the stone is heavier than the whole of the water in the vessel, for, if it were heavier than a portion of water of *its own bulk*,* it must sink, though all stones are not

* It is an axiom in hydrostatics, that every substance which *swims* on water displaces so much of that water as is exactly equal to its own weight; whereas, when a substance *sinks* in water, it displaces water equal to its bulk.

Exp.—Take a piece of hard wood, balance it accurately in a pair of scales with water, and then place it gently on the surface of water in a vessel exactly filled with that fluid, and it will displace a portion of the water, which will flow over the top of the vessel. If the wood

heavier than water, for these natural bodies differ much in specific gravity: *e. g.*, though the specific gravity of barytes is 4.40, or nearly $4\frac{1}{2}$ times as heavy as an equal bulk of water, some species of asbestos are nevertheless lighter than water. Some kinds of pumice-stone are also much lighter than that fluid.

Q. What is meant by specific gravity?

A. Specific gravity is a term used to express the relative weight of bodies?

Ex.—The specific gravity of one body may be much greater than that of another, though their absolute weights be the same. But when one body is larger, or occupies more space than another of the same weight, the first is said to be specifically lighter than the other, and *vice versa*. It is on this principle that an air balloon inflated with gas floats in the atmosphere; in consequence of its being specifically lighter than an equal volume of common air.

Q. How is the specific gravity of bodies denoted in chemical writings?

A. By comparing it with the specific gravity of pure water, in decimal figures, water being always considered as 1,000: *e. g.*, the specific gravity of the strongest sulphuric acid of commerce is said to be 1.900, or nine-tenths heavier than water. Iron is 7.650, or more than $7\frac{1}{2}$ times heavier than water; that is, a cubic inch of iron, if put into a scale, would require $7\frac{1}{2}$ inches of water to balance it. Silver is 10.478; gold, 19.300; and platinum 23.000, or 23 times heavier than water.

Q. What is the specific gravity of atmospheric air?

A. A cubic foot of atmospheric air weighs

be now taken out with care, it will be found that the water in the scale will exactly fill the vacancy left by the wood,

nearly one ounce and a quarter, and a cubic foot of water 1000 avoirdupoise.*

Q. How is water retained in the atmosphere, if its specific gravity be greater than that of atmospheric air?

A. Because the water taken up by the atmosphere is not in an aqueous state, but is converted into vapour by the matter of heat.

Obs.—Water not only becomes converted into steam by heat, but if the air be warm, the steam becomes as far changed by its union with the matter of heat as to be perfectly invisible.

Q. By what means is water converted into vapour by means of heat?

A. A considerable portion of the matter of heat combining chemically with water renders it specifically *lighter*, which is the cause of its rising and mixing with the atmosphere.

Q. What becomes of the water which thus evaporates from the earth?

A. It occupies the lower regions of the atmosphere, where it is preserved and partly dissolved in air, and partly in the state of elastic vapour.†

Obs.—By the experiments of Saussure, he makes it appear that a cubic foot of atmospheric air will hold in solution eleven grains of water, a property from which we derive many advantages. . It has a tendency to preserve every thing on the face of the earth in a proper degree of moisture. During one

* Atmospheric air, like all other elastic fluids, yields to the slightest impulse, and is put in motion with the greatest ease; but it has not the power of penetrating many substances, like oils and other fluids. The facility and rapidity of its motions cannot be explained on any other principle but its fluidity. Some of the winds move nearly at the rate of 4000 feet in a minute.

† From the experiments of some aeronauts, it would appear that the air is much drier in the higher regions than it is near the surface of the earth.—*Phil. Mag.* vol. xix. p. 378.

season of the year, in the interior of Africa, a wind, called the Harmattan, prevails, which is so extremely dry that household furniture is destroyed by it; the pannels of wainscots split; boarded floors are laid open; and the scarf skin of the body peels off, during its continuance. Were it not then for the property of the atmospheric air holding water in solution, this would be more or less the case everywhere.

Q. Explain the formation of vapour into clouds?

A. After vapour has remained for some time in the atmosphere, it becomes, in a measure, condensed by causes which are unknown to us; and the particles of water of which it is composed unite, and form small hollow vessicles, which accumulate together; and hence clouds are produced.

Obs.—Saussure conjectures that it is the electrical fluid which surrounds these vessicles, and prevents them from dissolving in the air. These vessicles are said to be from 1.380 to 1.190th of a line in diameter. See also Darwin's *Theory of Rain and Dew*, in notes to the *Botanic Garden*, 4to. part 1. pp. 114, and 169; and 16 and 17th vols. of *Philos. Mag.* In an *Essay on the Forms which Clouds assume*; by Luke Howard.

Q. What is the result of this change of vapour?

A. Vapour, when condensed, becomes too heavy for the air to support, and falls down in rain, hail, or snow. (See *Vaporisation*.)

CHAPTER III.

ATMOSPHERICAL AIR.

Q. WHAT are the perceptible properties of atmospherical air?

A. Fluidity, elasticity, expansibility, gravity.

1. Fluidity.

2. Elasticity—if atmospherical air be compressed into a small compass, it has the property of recovering its former state as soon as the pressure is removed; which principle is called its elasticity.

Ex.—A bladder tied up with the least quantity of air in it, and put under the receiver of an air pump, will be seen gradually to inflate in proportion as the pump is exhausted, till it becomes of its full size: placed before the fire the same effect will be produced, which dilates in this manner as the atmospheric pressure is removed. A wrinkled apple, from the same cause, becomes plump and smooth.* The elasticity of the air is also proved by carrying a bladder half full of air to the top of a high mountain; as the air will be gradually perceived to expand as it approaches the summit.

3. Expansibility, or that property of being rarefied by heat, so as to occupy a larger space than it otherwise would.

Ex.—The neck of a bladder, containing a small quantity of air, closely tied up and held to the fire, will, by the swelling

* Such, indeed, is the elasticity of the air, that Mr. Boyle caused it to dilate by means of an air pump, till it nearly occupied fourteen thousand times the space it usually does.

of the bladder, in consequence of the rarefaction of the air, afford an idea of the expansibility of the air.

Q. How far does the atmosphere extend?

A. The atmosphere is several miles high, but how far it extends is not exactly known.

Q. What is its use?

A. The use of the atmosphere is to support both animal and vegetable life. It is also necessary in every instance of combustion;* it ministers to several of the pleasures we derive from our senses; it gives buoyancy to the clouds, and enables the feathered creation to transport themselves with ease from one part of the earth to another.

Obs.—Were it not for atmospheric air, we should be unable to converse with each other; we should be unacquainted with sound, smell, or of the pleasures which arise from the variegated prospects with which we are surrounded. It is also this great extension of the atmosphere which occasions its *weight*, the pressure of which produces many important effects in the economy of nature.

Exp.—The pressure of the atmosphere may be illustrated by the following simple experiment:—place a card on a wine glass filled with water, then invert the glass, and the water will not escape; the pressure of the atmosphere on the outside of the card being sufficient to support it.

2. The same may be demonstrated by inverting a tall glass jar in a dish of water, and placing a lighted taper under it. As the taper consumes the air in the jar, its pressure becomes less on the water immediately under the jar; while the pressure of the atmosphere on the water *without* the circle of the jar

* There is one exception to this axiom. If a combustible substance be mixed with one-fourth or half its weight of nitre, or with oxygenized muriate of potass, it will burn if atmospheric air be excluded. But this is owing to oxygen, one of the principles of the atmosphere, being afforded by these salts.

remaining the same, part of the water in the dish will be forced up into the jar, to occupy the place of the air consumed by the taper.

3. The reality of atmospheric pressure may likewise be explained and demonstrated by a common barometer, merely by showing how it acts upon that instrument—a phenomenon beautifully illustrated in the following couplet:—

“ In tubes of glass mercurial columns rise
Or sink, obedient to the incumbent skies.”

Obs.—It is this pressure of the atmosphere which enables the limpet to attach itself to the rocks. It forms a vacuum in its pyramidal shell, and the pressure of the atmosphere supports it where it wishes to remain, without any further effort of its own.

Q. What are the effects produced by the weight of the atmosphere?

A. By the weight or pressure of the atmosphere we are enabled to raise water by the common pump, and to perform many other useful operations.

Obs.—The atmosphere presses equally upon the whole surface of the well, until the rod of the pump is moved; but, by forcing the rod down, the bucket compresses the air in the lower part of the pump-tree, which, being elastic, forces its way out of the tree through the valve; so that, when the bucket is again raised, that part of the pump-tree under the bucket is void of air; and the weight of the atmosphere pressing upon the body of the water in the well, forces up a column of water to supply its place; the next stroke of the pump-rod causes another column of water to rise; and as long as the bucket fits the pump-tree close enough to produce a vacuum, a constant stream of water may be drawn from below. The rise of water in a pump was formerly attributed to the horror nature had of a vacuum. This absurd notion was refuted about the middle of the 17th century. The fact, indeed, remained inexplicable till philosophers caught the idea of atmospheric pressure; since then, the suspension of

mercury in the barometer, and water in a pump, have been well understood.

" Pressed by the incumbent air the floods below,
Through opening valves, in foaming torrents flow,
Font after font in lessened impulse move,
And rising seek the vacancy above."

By cutting a piece of pasteboard in the form of a valve, and fixing it in a glass tube of a large bore, it will not be difficult to explain how the succional columns of water force up the valve in the pump-tree, and how that valve supports the water when raised, and prevents its return.

A common syringe will demonstrate the action of atmospheric air in pumping. When a child sucks at the breast, it forms a vacuum with its mouth, and the milk flows on the same principle. In like manner, a vacuum is formed between a piece of wet leather, tied to a string, and a pebble stone; and, by means of the pressure of the atmosphere, the leather is enabled to lift and carry about the stone suspended. The common syphon also is indebted to this pressure for its action.

Q. What other advantages are derived from the extension of the atmosphere?

A. If, for instance, there was little or no atmosphere, there would be no cold water, as the waters on the surface of the earth would be all evaporated at a very low temperature: besides, the arterial vessels of all organized beings would be so constantly distended, as to endanger both animal and vegetable life.

Obs.—On the tops of high mountains water will boil much sooner than on the plains, where the atmosphere is heavier; and it is known that many spirituous liquors, such as ether and spirits of wine, lose a great part of their qualities when exposed at such heights. And the quick evaporation which would take

place if we had no atmosphere, may be shewn by the pulse glass invented by Dr. Franklin. This consists of a small tube with a bulb at each end, exhausted of its air, and containing a small quantity of spirits of wine. If this instrument be held sloping, with one end in the palm of the hand, the heat of the hand will quickly cause the spirits to boil; but the vapour rising to the other end becomes condensed as soon as it comes in contact with the cold glass. This cheap and simple experiment shows that a very small degree of heat would be sufficient to evaporate all our fluids, if we had no atmosphere. It is also calculated to shew that evaporation produces cold; for the instant the spirit begins to boil, a sensation of cold is felt on that part of the hand where the bulb rests.*

Q. In what manner are waters and other fluids preserved to us by the weight of the atmosphere?

A. The weight of the atmosphere pressing on the water binds it down, as it were, and prevents the usual heat of the sun from converting this and all other fluids on the face of the earth into vapour.

Exp.—The following experiment will shew, that, if we had no atmosphere, the waters on the surface of the earth would be dissipated in vapour by a small degree of heat:—Procure a bottle with a very long neck, fill it with boiling water and cork it close, so as to exclude the air; then, if it be put to stand in a basin of cold water, the water will sink in the neck of the bottle as it cools. This shrinking of the hot water will produce a vacuum in the upper part of the bottle, and the water within it will be seen to commence boiling again with great violence. The cause of this is the cork taking off the pressure of the atmosphere from the water. Also, water which has been cooled

* It is this principle of *evaporation producing cold*, that occasions the injury which persons sustain by sitting in wet clothes, as it is not the water that hangs upon them which produces the injury, but the sudden loss of a large portion of caloric, which is carried off from the body by the evaporation of this water. If a healthy person were closely covered up with his wet clothes, so that no evaporation could take place, he would probably sustain no mischief.

many degrees below the boiling point, will recommence boiling if placed under the receiver of an air pump, as soon as we begin to exhaust the receiver of its air.

Obs.—Under the pressure of the atmosphere water boils at 212° , but in vacuo it boils when heated only to 67° . On the contrary, if additional pressure be given to water by Papin's digester, it may be heated to 400° without ebullition. Lead has often been melted by the water heated in these digesters.

Q. What is the weight of the atmosphere?

A. Every square foot of the earth's surface sustains about 2160 pounds of atmospheric air. A column of air, an inch square, weighs about fifteen pounds.

Q. What are the beneficial effects produced by the weight of the atmosphere upon the animal and vegetable creation.

A. The uniform pressure of the atmosphere on the *exterior* of all organised beings, counterpoises the *internal* pressure of the circulating fluids, and preserves the vessels in due vigour and tone. The great thickness of the atmosphere gives a proper temperature to the rays of the sun. It also reflects those rays so as to give a lucid brightness to every part of the heavens; and is the cause of those dews and rains which fructify the earth.

Q. What are the component parts of our atmospheric air?

A. Oxygen air and nitrogen air combined in certain proportions, with one part in every thousand of carbonic acid gas, and several adventitious substances. (See *Oxygen* and *Nitrogen*.) It also holds in solution a portion of water; and sometimes contains hydrogen and carburetted hydrogen gases.

Q. Are there any chemical means of analysing atmospheric air?

A. By the operation of different agents, the several gases may be separated from each other, and the quantity of each ascertained. (See *Gases and their Properties.*)

Exp.—If a measure of atmospheric air be confined over a portion of sulphuret of lime, it will soon be decreased to nearly one-fourth of its volume; its oxygen will be absorbed by the sulphuret, and the remaining air will be found to be incapable of supporting combustion. A piece of phosphorus will decompose atmospheric air in like manner.

Obs.—The chief chemical properties of the atmosphere are owing to the presence of oxygen gas. Air, from which this principle has been withdrawn, is nearly inert. It can no longer support respiration and combustion, and metals are not oxidized by being heated in it. Most of the spontaneous changes which mineral and dead organized bodies undergo, are owing to the powerful affinities of oxygen. The uses of nitrogen are in a measure unknown. It was supposed to act as a mere diluent to the oxygen; but it most probably serves some useful purpose in the economy of animals, the exact nature of which has not yet been discovered.

CHAPTER IV.

OF CALORIC.

Q. EXPLAIN the meaning of caloric.

A. Caloric is the name modern chemists have given to the matter of heat, which, in common

language, has two meanings. In the one case, it implies the sensation we experience on touching a hot body; in the other, it expresses the cause of that sensation.

Q. What are the properties of caloric?

A. On the supposition that caloric is material, it is a subtle fluid, the particles of which repel one another, and are attracted by all other substances. It is imponderable; that is, it is so exceedingly light that a body undergoes no appreciable change of weight, either from the addition or subtraction of caloric. It is present in all bodies, and cannot be wholly separated from them.

Ex.—Take any substance whatever, at any temperature, however low, and transfer it into an atmosphere, whose temperature is still lower, a thermometer will indicate that caloric is escaping from it. That its particles repel one another, is proved by observing that it flies off from a heated body; and that it is attracted by other substances is equally manifest, from the tendency it has to penetrate their particles, and be retained by them.

Q. Give an instance of the manner in which caloric may be transferred from one body to another?

A. If a cup of mercury at 60° be plunged into hot water, caloric passes rapidly from one into the other, until the temperature in both is the same:—that is, till a thermometer placed in each of them stands at the same height.

. All bodies on the earth are constantly tending to attain an equality; or, what is technically called, an equilibrium of temperature.

Ex.—If a number of substances, different in temperature, be inclosed in an apartment in which there is no actual source of

caloric, they will soon acquire an equilibrium, so that a thermometer will stand at the same point in all of them. The varying sensations of heat and cold are owing to a like cause. On touching a hot body caloric passes from it into the hand, and excites the feeling of warmth; when we touch a cold body caloric is communicated to it from the hand, and thus the sensation of cold is produced.

Q. How is caloric distributed among surrounding objects?

A. In order that caloric may be distributed at sensible distances, it is not necessary that the body should be in *vacuo*, as it passes with equal facility through the air as through a vacuum. Hence it follows, that in establishing an equilibrium of temperature, caloric is distributed among the surrounding objects in two ways;—partly through the means of intermediate bodies, or by communication; partly in consequence of an interchange established from a distance, or by radiation. Caloric passes through bodies with different degrees of velocity. Some substances offer very little impediment to its passage, whilst it is transmitted slowly through others.

Ex.—Though we cannot leave one end of a rod of iron for some time in the fire, and then touch its free extremity without danger of being burnt, yet this may be done with perfect safety if the rod be of glass or of wood. The caloric will speedily traverse the iron bar, so that at the distance of a foot from the fire it is impossible to endure the heat; while a piece of red hot glass, two or three inches from its extremity, may be held in the hand; or a piece of burning charcoal, though the part in combustion be only a few lines removed from the skin.

Obs.—These and similar facts have led to a division of bodies into conductors and non-conductors of caloric. The conductors, of course, include those bodies which allow caloric to

pass freely through their substance, such as metals; and the non-conductors comprise those which do not give an easy passage to it, as wood, charcoal, stones,* &c. The conducting power of solid bodies does not appear to be related to any of the other properties of matter; but it approaches nearer to the ratio of their densities than to that of any other properties. Count Romford found a considerable difference in the conducting power even of the same material, according to the state in which it was employed. (See *Phil. Trans.* 1792.) His observations seem to warrant the conclusion, that in the same substance the conducting power increases with the compactness of structure.

In one sense of the word, liquids may be said to have the power of communicating caloric with great rapidity, and yet they are very imperfect conductors. When certain particles of a fluid are expanded by heat, they become specifically lighter than those which have not yet received an increase of temperature—consequently, according to a well known law in physics, they must rise towards the upper surface of the liquid, while their place is supplied by the adjoining particles, which are colder and denser, and therefore disposed to descend. Hence, under certain circumstances, caloric is rapidly communicated through fluids; that is, if heat be applied to the bottom of a vessel containing any liquid; a double set of currents

* Various methods have been adopted to determine the relative conducting power of different substances. The most convenient is that of Ingenhouz (See *Jour. de Phys.* 1789, p. 68). He covered little rods of the same form, size, and length, but of different materials, with a layer of wax, plunged their extremities into heated oil, and noted to what distance the wax was melted on each during the same interval. By this method, the metals were found to conduct caloric better than any other substances—and of these silver is the best, gold next, then tin and copper, which are nearly equal, then iron, platinum and lead.

tions.* As, according to the laws of nature, animal and vegetable life are both very much influenced by the temperature in which they exist. Different kinds of vegetables, therefore, and a different race of animals, are found appropriated to the different climates of the earth.

2. *Caloric by combustion.* The oxygen gas of the atmosphere is decomposed by combustion; and caloric, one of its component parts, is set at liberty.

3. *Caloric produced by percussion.* The heat produced by percussion is generally occasioned by the compression of the particles of the body which forces out a portion of its latent heat or caloric.

Obs.—As evaporation produces cold, condensation always occasions heat; that is, caloric is always evolved by those bodies which have undergone any degree of condensation. In one case caloric is absorbed, and in the other it is set at liberty. By the collision of flint and steel so much caloric is disengaged, that the metallic particles struck off, are actually melted by it. This is evident from their being always found in a spherical form.

4. *Caloric by friction.* It is not known how friction produces caloric, unless we suppose it to be a succession of percussions—or probably it is to the agency of electricity or galvanism alone, that the cause must here be ascribed.

Obs.—The method of procuring fire, practised by the natives of California, is too well known to be repeated; and instances have occurred, where whole forests have been burnt

* Caloric comes to us from the sun at the rate of 200,000 miles in a second of time; but Dr. Herschel has proved that the solar rays which occasion heat, are distinct from those which luminate and produce vision.

down, by fires kindled from the violent friction of the branches against each other by means of the wind.

5. Caloric by means of electricity or galvanism. By the discharge of an electrical battery, or by the galvanic apparatus, a more intense degree of caloric may be obtained than by any other means whatever.

Exp.—If a piece of charcoal, from hard wood, be inflamed by galvanism, the light produced seems to vie with that of the sun, being too intense for the eye to endure. By means of the electrical battery, metals may be suddenly fused, and gases united; but if a fine metallic wire be made part of a powerful galvanic circle, it will be melted in an instant, and gives out the most beautiful corruscations of light of various colours, according to the nature of the metal employed. In like manner, gold and silver leaf, when submitted to galvanic action, burn with the greatest splendour, and afford extremely beautiful appearances.

6. Caloric by mixture. When heat is produced by the mixture of two or more substances, it is owing to the fluid part of the mixture taking a more solid form; for neither water nor any other fluid can acquire an increase of density without giving out a portion of its latent caloric.

Exp.—When two gases or liquids unite *chemically*, the compound has greater density than the mean density. Thus the vapour of water at the boiling point occupies much less space than the hydrogen and oxygen gases, which compose it, would have occupied at the same temperature.

2. Sulphuric acid and water experience this condensation by mixture, which is proved by the measure of fluids, before and afterwards, and by the heat that is evolved. If four parts of the former be mixed with one of the latter, the mixed fluids will quickly acquire a temperature higher than that of boiling water. Some caution is necessary in making this experiment.

3. If iron filings and sulphur be mixed into paste with water,

a sulphuret of iron will be formed, which decomposes the water and absorbs oxygen so rapidly that the mixture takes fire, even though it be buried under ground.

Obs.—Mixture does not uniformly produce heat. The mixture of some substances produce an intense cold. The cause, however, of both effects is easily explained. Whenever substances become more condensed by mixture, heat is evolved; when they expand cold is produced; or, in other words, the compound has a greater or less capacity for caloric than the separate ingredients. The mixture of muriate of lime and snow produces the greatest degree of cold yet known.

Q. Is there any difference in the nature of caloric?

A. There is not: we have reason to believe that caloric is uniform in its nature; but the terms *sensible heat* or free caloric, latent heat or combined caloric are necessary, because there exists in all bodies two portions of caloric very distinct from each other, which are thus designated.*

Q. What is meant by free or sensible caloric?

A. It is the matter of heat disengaged from other bodies, or, if united, not chemically so, with them.

Q. What is latent caloric?

A. It is that portion of the matter of heat which makes no sensible addition to the temperature of the bodies in which it exists; and in this state it is known to exist in all substances we are acquainted with; which is not the case with any other bodies we know of, not even light.

Q. What are the particular effects of caloric on bodies?

A. Caloric favours the solution of salts, and

* We are indebted to Dr. Black for the discovery of latent heat.—
See *Preface to his Lectures*.

promotes the union of many substances. In other cases it serves to separate bodies already united; so that in the hands of chemists it is the most powerful agent they are acquainted with. It also promotes the decomposition of bodies, in consequence of its counteracting the attraction of cohesion which exists in all bodies.

Ex.—Put two ounces of Glauber's salts (sulphate of soda) in powder, into a tea-cup of cold water, stirring them together, and the water will only dissolve a portion of the salt; but if heat be applied the whole will be dissolved. If the liquor be left to cool, the salt will be seen to shoot into crystals, affording also an example of chrySTALLIZATION.

2. Sulphur and mercury may be mixed without any apparent change; but if caloric be added, and the heat properly regulated, they combine so intimately as to form vermilion. Charcoal seems to have no attraction for oxygen in the atmospheric temperature, but if heated it unites to it with great eagerness.

Obs.—Caloric is also the cause of fluidity in all substances which are capable of becoming fluid, from the heaviest metal to the lightest gas. By the abstraction of caloric solid bodies rendered fluid by it are reproduced.

Q. What are the terms used by chemists to express the different proportions of caloric of which bodies are more or less susceptible?

A. One body is said to have a greater *capacity* for caloric than another, and *vice versa*.

Ex.—The property of this term may be shown to the chemical student by dipping a lock of wool and a piece of sponge in water, and directing him to observe how much more water the sponge is capable of taking up than the wool. Hence sponge may be said to have a greater *capacity* for water than wool has.

Q. What term is used to denote the quantity

of caloric necessary to raise a body to any given temperature?

A. The specific caloric of that body.

Obs.—This term is always used comparatively, expressive of the relative portions of caloric contained in equal weights or measures of different bodies at the same temperature, or the comparative quantity of caloric which can produce the same effect. Thus, if the specific caloric of mercury be said to be one, that of water may be said to be three, as in the following:

Exp.—Take 1lb. of water at 100° and mix it with 1lb. of water heated to 200°, the mixture will be found to give the exact mean temperature of 150°; but 1lb. of mercury at 100° and 1lb. of water at 200°, will produce a heat much higher than the mean temperature: mercury, therefore, has not so great a *capacity* for caloric as water.

. Bodies usually become more dense by the loss of caloric; but the freezing of water is a striking exception to this general law of nature. There are some few other exceptions. Saline solutions expand in cooling as crystallization takes place; and more perfect castings of iron may be had than of almost any other metal, in consequence of iron enlarging always as it cools, and filling the most minute parts of the mould into which it may be poured in a fluid state; but we know of no fluids that has a *maximum* of density like water, and that expands whether heated above or cooled below that temperature: for water as it cools below 45° 5' instead of contracting and becoming of greater specific gravity, actually becomes increased in bulk, and its specific gravity begins to lessen as it cools.

EFFECTS OF CALORIC.—*Q.* What are the phenomena which accompany the passage of caloric into substances?

A. Expansion, liquefaction, vaporization, incandescence and combustion.

Q. What are those that attend its escape?

A. The phenomena which attend the escape

of caloric from substances are :—contraction, solidification of fluids, and condensation of vapour. As these last, however, are simply the converse of the former, all the effects of caloric upon matter, may be arranged under the five heads which have previously been mentioned.

EXPANSION.—All bodies are expanded by caloric, and the expansion of the same body increases with the quantity of caloric which enters it. But this law is a general one, only so long as the body under examination suffers no change in its form or composition. If the caloric should produce one or both these effects, then the reverse of expansion (cohesion) may ensue; not, however, as the direct consequence of an augmented temperature, but as the result of a change in form or composition.

To prove the expansion of solids. Take the exact dimensions in length, breadth, and thickness of every substance, when cold, and measure it again while strongly heated, when it will be found to have increased in every direction.

2. Adapt a ring to an iron rod, the former being just large enough to permit the latter to pass through it while cold. The rod is next heated, when it will no longer pass through the ring. This dilatation from heat, and consequent contraction in cooling, takes place with a force which appears irresistible.

. The expansion of solids has engaged the attention of experimenters,* whose efforts have been chiefly directed to—

* The Philosophical Transactions of London contain various dissertations on this subject by Ellicot, Smeaton, Troughton, and General Roy; and M. Biot, in *Traité de Physique*, vol. i., has given the results of experiments with great care by Lavoisier and Laplace.

wards ascertaining the exact quantity by which different substances are lengthened by a given increase of heat, and determining whether or not their expansion is equable at different temperatures.

The simplest mode of proving the expansion of liquids is by putting a common thermometer, made with mercury or alcohol, into warm water, when the dilatation of the liquid will be shewn by its ascent in the stem.

Obs.—This experiment is illustrative of two facts:—1. That the dilatation is in proportion to the temperature: for if the thermometer be plunged into several portions of water heated to different degrees, the ascent will be greatest in the hottest water, and least in the coolest portions. 2. It demonstrates that liquids expand more than solids. The glass bulb of the thermometer is itself expanded by the hot water, and therefore is enabled to contain more mercury than before; but the mercury being dilated to a much greater extent, not only occupies the additional space in the bulb, but likewise rises in the stem. Its ascent marks the difference between its own dilatation and that of the glass.

Different fluids do not expand to the same degree from an equal increase of temperature. Alcohol expands much more than water, and water than mercury.

THE THERMOMETER.

"In tubes of glass mercurial columns rise
Or sink, obedient to the incumbent skies;
Or, as they touch the figured scale, repeat
The nice gradations of circumfluent heat."

Barwin.

Q. What is a thermometer?

A. A thermometer is an instrument in common use to measure the temperature of bodies. It consists of a glass tube containing a portion of mercury, with a graduated plate an-

nexed to it. The tube is hermetically sealed, to preserve the metal from the pressure of the atmosphere.

Q. How is a thermometer affected by the temperature of bodies?

A. When a thermometer is brought in contact with any substance, the mercury expands or contracts till it acquires the same temperature; and the height at which the mercury then stands in the tube, indicates the exact temperature of the substance to which it has been applied.

Q. Will the thermometer show the quantity of caloric in all bodies.

A. No: it will not shew that portion of caloric which is latent, or chemically combined with any body: *e. g.*, fluids require a certain portion of caloric to keep them in a state of fluidity, which portion is not indicated by the thermometer.

Obs.—The property which we call the temperature of bodies does not shew the measure of their caloric, but merely the degree of dilatation which the caloric they contain in a disengaged state is capable of producing in the substance of which the thermometers are formed.

* * Every substance requires its own quantity of caloric to raise it to a given temperature; but when raised to that temperature, every further addition of caloric is precisely shown by the thermometer.

All fluids operate upon the thermometer in the same manner as solids; for, whatever sensible colour be contained in any liquid, that portion is accurately shewn by the thermometer. Nature is uniform in all her results; for, if we plunge a thermometer ever so often into boiling water, it will always stand at the same point,

provided the pressure of the atmosphere be the same. Melting snow will always show the same degree upon the thermometer, in whatever state the atmosphere may be.

Ex.—If a quantity of snow be placed in a bason before the fire, and a thermometer be plunged in it, the thermometer will stand at 32° : if the instrument be removed, and the snow suffered to remain before the fire some time longer, and then tried by the thermometer, it will still indicate the same temperature, though it has all along been receiving an accession of caloric; but the moment that the *whole* of the snow is melted the thermometer will begin to rise.

2. Suppose also a piece of ice, cooled 20° below the freezing point, be exposed to a hot fire with a thermometer fixed in it, the thermometer will rise very uniformly till it comes to the freezing point 32° , and then make a full stop till the ice is all liquified, as though the fire had lost its faculty of heating: but the instant that all the ice is melted, the thermometer will begin to rise again, and continue to rise gradually till the water becomes heated to 212° , the boiling point.

.*.* These experiments show that the heat which snow and ice receive while melting is necessary to give them fluidity, though it does not increase their temperature; and that contains much less absolute caloric than water at the same temperature. Were this not the case, all cold countries would be subject to dreadful inundations; for, whenever the atmosphere became warmer than 32° , the ice and snow would be melted *in an instant*, and the sudden deluge of water would carry every thing before it.

CALORIC OF FLUIDITY.—The caloric of fluidity is that portion of heat which is a necessary part of fluids; though different fluids require different portions of it to preserve them in the state of fluids.

Exp.—If four parts of sulphuric acid and one part of ice, both at the temperature of 32° , be mixed together, the ice melts

instantly, and the temperature of the mixture rises to 212° (the heat of boiling water). But if four parts of ice and one of the same kind of acid at 32° be mixed, the temperature sinks to about 4° .

Obs.—In the first of these experiments, as the ice and acid combine, they become more dense than their *mean* density; consequently they both give a portion of their caloric of fluidity, and retain only the caloric of fluidity which is necessary for the new compound. In the second experiment, the ice, assuming a liquid form, requires a large dose of caloric to give it fluidity; and the sudden fall of the thermometer is owing to the suddenness with which the ice absorbs the caloric from the acid, and which it requires before it can assume a liquid form.

According to Dr. Irvine the caloric of fluidity of

Sulphur is .	143°	68°	Fahrenheit	
Water . . .	140°	Lead . . .	162°	F.
Spermaceti	145°	Zinc . . .	493°	
Bees wax .	175°	Tin . . .	500°	
Tin . . .	500°	Bismuth . . .	550°	

It has been remarked by Bishop Watson,* that nitrous acid mixed with snow water excites a very great degree of heat, but when mixed with snow produces the greatest cold he had ever observed.

HEAT AND COLD.—The power of producing cold is still very limited compared with that of exciting heat. Hitherto no one has been able to sink the temperature of any substance below 90° or 112° below the freezing point of water; but Mr. Wedgewood constructed an air furnace in which he raised a heat equal to 185 degrees of his pyrometer,† or 25127° of Fahrenheit; and

* Chemical Essays, vol. iii. p. 142.

† To measure degrees of heat in high temperatures, including a range of nearly $32,000^{\circ}$ of Fahrenheit; for a description of which, see *Philosophical Transactions*, vol. lxxii.

by means of oxygen gas more intense heats than even this have been produced.

RANGE AND REGULATION OF THERMOMETERS.

—In this kingdom Fahrenheit's thermometer is universally used. In it the range between the freezing and boiling points of water is divided into 180° ; and as the greatest possible degree of cold was supposed to be that produced by mixing snow and muriate of soda, that was made the Zero; thus the freezing point became 32° , and the boiling point 212° .

The centigrade thermometer of modern France places the Zero at the freezing point, and divides the range between it and the boiling point into 100° . This has long been used in Sweden under the name of Celsius' thermometer.

Reaumur's thermometer, formerly used in France, divides the space between the freezing and boiling of water into 80° ; and, like the centigrade thermometer, places the Zero at the freezing point.

De Lisle's thermometer is used in Russia. The graduation commences at the boiling point, and increases towards the freezing point. The boiling point is marked O, and the freezing point 130° .

In Wedgewood's pyrometer the Zero corresponds with 1077° of Fahrenheit, each degree of which is equal to 130° of Fahrenheit. Therefore 180° F. = 100° C. = 80° R. = 150° De L. =
¹⁸ W.*

* For an easy method of reducing the degrees of one thermometer to the scale of another, see "THE NEW LONDON MEDICAL AND SURGICAL DICTIONARY," by the Author.

LIQUEFACTION.—All bodies, hitherto known, are either solid, liquid, or gaseous; and the form they assume depends on the relative intensity of cohesion and repulsion. Should the repulsive force be comparatively feeble, the particles will adhere so firmly together, that they cannot move freely upon one another, thus constituting a solid. If cohesion be so far counteracted by repulsion, that the particles move on each other freely, a liquid is formed. And should the cohesive attraction be entirely overcome, so that the particles not only move freely over each other, but separate from each other to an indefinite extent, unless restrained by external pressure, an æriform substance will be produced.

The most material circumstance as regards liquefaction is the discovery made by Dr. Black; namely,—that a large quantity of caloric disappears, or becomes insensible to the thermometer during the process; which he illustrates by the following

Exp.—If a pound of water at 32° be mixed with a pound of water at 172° , the temperature of the mixture will be intermediate betwixt them, or 102° . But if a pound of water at 172° be added to a pound of ice at 32° , the ice will quickly dissolve, and in placing a thermometer in the mixture, it will be found to stand, not at 102° , but at 32° .

Obs.—In this experiment, the pound of hot water, which was originally at 172° , actually loses 140° of caloric, all of which entered into the ice, and caused its liquefaction, but did not affect its temperature. It therefore follows that a quantity of caloric becomes insensible during the melting of ice sufficient to raise the temperature of an equal weight of water 140° of Fahrenheit. This explains the well-known fact on which the graduation of the thermometer depends; namely, that the temperature of melting ice or snow never exceeds 32° F. All the

caloric which is added becomes insensible, till the liquefaction be complete.*

VAPORISATION. — Æriform substances are commonly divided into vapours and gases. The character of the former is, that they can be readily converted into solids or liquids, either by a moderate increase of pressure, the temperature at which they were formed remaining the same, or by a diminution of temperature, the pressure being unchanged. Gases, on the contrary, retain their elastic state more obstinately; they are always sent at common temperatures, and cannot be made to change their form, except by being subjected to much greater pressure than they are naturally exposed to. Several of them, indeed, have hitherto resisted every effort to compress them into liquids.

Vapours occupy more space than the substances from which they are produced; and it is a general opinion that a sufficiently intense heat would convert every liquid and solid into vapour. A considerable number of bodies, however, resist the strongest heat of our furnaces without vapourizing. These are said to be fixed in the fire; those which, under the same circumstances are converted into vapour, are called volatile.

According to the experiments of Gay Lussac, in passing into vapour—

			Times its volume.
Water expands	-	-	1696
Alcohol	-	-	650
Ether	-	-	443

* Freezing mixtures may be made without the use of snow or ice, by the rapid solution of salts. For a table of these and frigorific mixtures, see New Lond. Med. and Surg. Dict.

This shews that vapours differ in density. Watery vapour is lighter than air in the proportion of 1000 to 1605, or the density of air being 1000, that of watery vapour is 623. The vapour of alcohol, on the contrary, is half as heavy again as air; and that of ether is more than twice and a half as heavy. As alcohol boils at a lower temperature than water, and ether than alcohol, it was conceived that the density of vapours might be in the direct rates of the volatility of the liquids which produced it. But Gay Lussac has shewn that this law does not generally hold; for the carbonate of sulphur boils at a higher temperature than ether, and nevertheless it forms the heaviest vapour. He also found that the dilatation of vapours by heat follows the same law as gases, that is, for every degree of Fahrenheit, they increase by $\frac{1}{480}$ th of the volume they occupied at 32°. But the law does not hold unless the quantity of vapour continues the same.

Obs.—Vaporisation is conveniently studied under two heads, —ebullition and evaporation. In the first, the production of vapour is so rapid, that its escape gives rise to a visible commotion of the liquid; in the second, it passes off quietly and insensibly.

EBULLITION.—The temperature at which vapours rise with sufficient force for causing the phenomena of ebullition, is called the boiling point. The heat requisite for this effect, varies with the nature of the fluid: *e. g.*

Sulphuric ether boils at	-	-	96° F.
Alcohol	-	-	173°
And pure water at	-	-	212°;—

while oil of turpentine must be raised to 316°,

and mercury to 660° , before either exhibits marks of ebullition.

The boiling point of the same liquid is constant, so long as the necessary conditions are preserved, although liable to be affected by several circumstances. The nature of the vessel has some influence upon it; for Gay Lussac observed, that pure water boils precisely at 212° F. in a metallic vessel; and at 214° in one of glass.

The circumstance, however, which has the greatest influence over the boiling point of fluids, is the variation of pressure. All bodies upon the earth are constantly exposed to considerable pressure. Liquids are exposed to this pressure as well as solids, and their tendency to take the form of vapour is very much counteracted by it. And as the atmospheric pressure is variable, it follows that the boiling point of liquids must vary also.

The influence of the atmosphere over the point of ebullition is best shown by removing its pressure altogether. The late professor Robinson, found that fluids boil in vacuo at a temperature 140 degrees lower than in the open air.* Thus water boils at 72° F., alcohol at 33° F., and ether at 44° F. This proves that a liquid is not necessarily hot, because it boils. The heat of the hand is sufficient to make water boil in vacuo, as exemplified by the common pulse glass (p. 16.); and ether, under the same circumstances, will enter into ebullition, though its temperature be low enough for freezing mercury.

Q. What is the reason that water, under common circumstances, cannot be heated beyond 212° F.?

* Wollaston, Phil. Trans. 1817.

A. Because it then acquires such an expansive force as enables it to overcome the atmospheric pressure, and to fly off in the form of vapour.

Q. In what manner may water then be heated to any extent without boiling?

A. By being subjected to sufficient pressure, which is best done by heating it, while confined in a strong copper vessel, called Papin's digester. A large quantity of vapour collects above the water, which checks the ebullition by the pressure it exerts upon the surface of the liquid.

Obs.—There is no limit to which water might not be heated in this way, provided the vessel be strong enough to confine vapour; but the expansive force of steam under these circumstances is so enormous as to overcome the greatest resistance. The power and advantages of steam to commerce in general have been as prophetically verified in the following lines as these lines are beautifully descriptive and truly poetical:—

"Soon shall thy arm, unconquer'd steam, afar,
Drag the slow barge, or drive the rapid car;
 Or on wide waving wings expanded bear
The flying chariot through the fields of air."

Steam is now employed in a vast variety of ways in the different manufactures of this kingdom; its application to navigation, and the prospect of its shortly being made subservient to inland travelling, renders it necessary, as connected with this subject, to say a little upon it.

In estimating the power of steam,* it should be remembered that vapour, if separated from the liquid which produced it, does not possess a greater elasticity than an equal quantity of air.

* Professor Robison (Brewster's Ed. p. 25) found that the tension of steam is equal to two atmospheres at 244° F., and to three at 270° F. The results of Mr Southern's Experiments, given in the same volume, fix upon 250—3° F. as the temperature at which steam has the force of two atmospheres, on 293—4° F. for four, and 343—6° F. for eight atmospheres.

Ex.—If the digester was full of steam at 212° , no water in the liquid state being present, it may be heated to any degree, even to redness, without danger of bursting. But if water be present, then each addition of caloric causes a fresh portion of steam to rise, which adds its own elastic force to that of the vapour previously existing, and, consequently, an excessive pressure is soon excited against the inside of the vessel.

The elasticity of steam is employed as a moving power in the steam engine. The construction of this machine depends on two properties of steam, namely, the expansive force communicated to it by caloric, and its ready conversion into water by cold. The effects of both these properties is well shown by a little instrument devised by Dr. Wollaston, which consists of a cylindrical glass tube, six inches long, nearly an inch wide, and blown out into a little ball at one end. A piston is alternately fitted to the cylinder, so as to move the tube up and down with freedom. When the piston is at the bottom of the tube it is forced up by causing a portion of water, previously placed in the ball, to boil by means of a spirit lamp. On dipping the ball into cold water, the steam which occupies the cylinder is suddenly condensed, and the piston is forced down by the pressure of the air above it. By the ultimate application of heat and cold, the same movements are reproduced, and may be repeated for any length of time. The moving power of the steam engine is the same as in this apparatus. The only essential difference between these is in the mode of condensing the steam. In the steam engine the steam is condensed in a separate vessel, where there is a regular supply of cold water for the purpose. By this contrivance, which constitutes the great

improvements of Watt, the temperature of the cylinder never falls below 212° .

FORMATION OF VAPOUR.—The formation of vapour is, like liquefaction, attended with a loss of sensible caloric. This is proved by the well known fact that the temperature of steam is precisely the same as that of the boiling water from which it arises; so that all the caloric which enters into the liquid is solely employed in converting a portion of it into vapour, without affecting the temperature of either in the slightest degree, provided the latter is permitted to escape with freedom. The caloric which then becomes latent, in the language of Dr. Black, is again set free when the vapour is condensed into water. The exact quantity of caloric absorbed may therefore be ascertained by condensing the steam in cold water, and observing the rise of temperature occasioned by it.

From the experiments of Dr. Black and Mr. Watt, conducted on the above principle, it appears that steam of 212° , in being condensed into water of 212° , gives out as much caloric as would raise the temperature of an equal weight of water by 950° , all of which had previously existed in the vapour without being sensible to a thermometer.

EVAPORATION.—Like ebullition, evaporation consists in the formation of vapour, and the only assignable difference between them is, that evaporation takes place quietly, and ebullition with the appearance of boiling.

Evaporation takes place at the common temperature, as may be seen by exposing water in a

shallow vessel to the air for a few days, when it will gradually diminish, and at last disappear.

Most fluids, if not all of them, are susceptible of this gradual dissipation; and it may also be observed in some solids, for instance, as in camphor.

Evaporation is much more rapid in some fluids than in others, and it is always found that those liquids, whose boiling point is lowest, evaporate with the greatest rapidity, *e. g.*; alcohol, which boils at a lower temperature than water, evaporates also more freely; and ether, whose point of ebullition is yet lower than that of alcohol, evaporates still more rapidly.

Q. What are the chief circumstances that influence the progress of evaporation?

A. Extent of surface, and the state of the air as to temperature, dryness, stillness and density.

1. *Extent of surface.* Evaporation proceeds only from the surface of fluids, and, therefore, *cæteris paribus*, must depend upon the extent of surface exposed.

2. *Temperature.* The effect of heat in promoting evaporation may easily be shown by putting an equal quantity of water into two saucers; one of which is placed in a warm, the other in a cold situation; the former will be quite dry before the latter has suffered any appreciable diminution.

3. *State of the Air as to dryness or moisture.* When water is covered by a stratum of dry air, the evaporation is rapid, even when its temperature is low. Thus, in some dry cold days in winter, the evaporation is exceedingly rapid; whereas it goes on very slowly, if the atmosphere contains much vapour, even though the air be very warm.

4. *Evaporation is far slower in still air than in a current.* The reason for this is obvious; the air immediately in contact with the water soon becomes moist, and thus a check is put to evaporation. But if the air be removed from the surface of the water when it has become charged with vapour, and its place is supplied with fresh air, then the evaporation continues without interruption.

5. *Pressure over the surface of liquids has a remarkable influence over evaporation.* To prove this, place ether in the vacuum of an air pump, when vapour will rise so abundantly as to produce ebullition.

As a large quantity of caloric passes from a sensible to an insensible state during the formation of vapour, it follows that cold should be generated by evaporation.

Exp.—If a few drops of ether be allowed to fall upon the hand, a strong sensation of cold will be excited during the evaporation; or if the ball of a thermometer, covered with lint, be moistened with ether, the production of cold will be marked by the descent of the mercury. But to appreciate the degree of cold which may be produced by evaporation, it is necessary to render it very rapid and abundant by artificial processes; and the best means of doing so, is by removing pressures from the surface of volatile liquids, &c.

Obs.—Liquids which evaporate more rapidly than water, cause a still greater reduction of temperature. The cold produced by the evaporation of ether in the vacuum of the air-pump is so intense as to freeze mercury.* Evaporation takes place equally in vacuo as in the air; and it is an established fact, that the atmosphere retards the progress; and that one of the best means of accelerating it, is by removing the air altogether.

* See a Paper by the late Dr. Marcet, in Nicholson's Journal, vol. xxxiv.

The experiments of Mr. Dalton prove that caloric is the true and only cause of the formation of vapour. He also finds that the actual quantity of vapour which can exist in any given space, is dependent solely upon the temperature.

Exp.—If a little water be put into a dry glass flask, a quantity of vapour will be formed proportionate to the temperature. If a thermometer placed in it stands at 32° F. the flask will contain a very small quantity of vapour. At 40° more vapour will exist in it; at 50° it will contain still more; at 60° the quantity will be still farther augmented: and if at this last degree the temperature of the flask be suddenly reduced to 40°, then a certain portion of vapour will be converted into water—the quantity which retains the elastic form being precisely the same as when the temperature was originally at 40° F.

The tension or elasticity of vapour, however much the pressure may vary, so long as the temperature remains constant and liquid, enough is present for preserving the state of saturation proper to the temperature, which alone determines its tension. The presence of watery vapour in the atmosphere is owing to evaporation. All the accumulations of watery vapour upon the surface of the earth are subjected by its means to a natural distillation; the impurities with which they are impregnated remain behind, while the pure vapour ascends into the air, gives rise to a multitude of meteorological phenomena, and after a time descends again upon the earth as rain. As evaporation goes on to a certain extent even at low temperatures, it is probable the atmosphere is never absolutely free of vapour; the quantity however, at all times, of the vapour present in the atmosphere is very variable, in consequence

of the continual change of temperature to which the air is subject: and even when the temperature is the same, the quantity of vapour is still found to vary, for the air is not always in a state of saturation. At one time it is excessively dry, at another it is fully saturated, and at other times it varies between these extremes. This variable condition of the atmosphere, as regards saturation, is ascertained by the hygrometer. *

CONSTITUTION OF THE GASES WITH RESPECT TO CALORIC.—The experiments of Sir Humphrey Davy, and Mr. Faraday, on the liquefaction of gaseous substances, seem to justify the opinion that gases are merely the vapours of extremely volatile liquors, whose boiling point, under the atmospheric pressure, is lower than any natural temperature; hence they are always found in a gaseous state; but by subjecting them to great pressure, their elasticity is so far counteracted that they become liquid. The process for condensing the gases, consists in exposing them to the pressure of their own atmospheres. Most of these experiments are attended with danger, from the bursting of the hermetically sealed tubes in which they are made, that it becomes necessary for the operator to protect himself with a mask. See *Philos. Trans.* for 1823.

* An instrument which points out the state of dryness and moisture of the atmosphere. The hygrometric condition of the air may also be determined by covering the bulb of a thermometer with a piece of silk or linen, moistening it with water, and exposing it to the air, which shew the rapidity of evaporation. The descent of the mercury, or the cold produced, will correspond to the quantity of vapour formed in a given time. Of this kind is Mr. Leslie's hygrometer.

CHAPTER V.

LIGHT.*

" Hail, holy light ! offspring of heaven first-born,
 Or of th' eternal co-eternal beam,
 Bright effluence of bright essence increate—
 Thy fountain who shall tell ?

Q. WHAT is light ?

A. Light is an extremely attenuated matter, constantly transmitted from the sun, its origin, to the earth.

Q. What is the nature of light ?

A. Light is a peculiar substance, the nature of which is little understood ; but it possesses many very singular and striking properties.

Obs.—Light is similar to caloric in many of its properties. They are both emitted in the form of rays, traverse the air in straight lines, and are subject to the same laws of reflection. The intensity of each diminishes as the square of the distance from their source : hence it has been supposed that light and heat might be modifications of the same agent ; and though

* With regard to light, we would mention the singularly useful, and hitherto unobserved *effect of moonlight*, in assisting the completion of certain important natural phenomena. The crystallization of water, under the form of those light frosts which so much prevail during the early spring, and which are of such important service in assisting the operations of agriculture, by rendering the surface of the earth mellow, and better susceptible of the manure that is necessary to it, are greatly assisted, and in many cases entirely brought about by the intervention of moonlight. It is well known, that under certain circumstances, water will sink to the temperature of 22° before it freezes, or takes the form of crystals. Indeed it will invariably do so in the absence of any mechanical agitation, and in the absence of light. It is an unquestionable fact, but one which has not hitherto been observed generally, or attended to, that during that period of the year which has been alluded to, and indeed at other periods, before the moon rises, on a still clear night, when the atmosphere is at a lower temperature than 32, the water remains in a liquid state, but immediately on the moon rising, and diffusing its light around, the water freezes, and performs the salutary offices required of it, without subjecting us to the severity of a low temperature.—*Gurney's Lectures on Chemistry.*

most persons regard them as independent principles, yet they are certainly allied in a way which at present is quite inexplicable.

Q. How many kinds of light are there ?

A. There are two kinds of light, natural and artificial ; the former proceeding from the sun and stars ; the latter from bodies strongly heated.

Q. In what manner are the solar rays transmitted to us ?

A. Either directly, as in the case of sunshine ; or indirectly, in consequence of being diffused through the atmosphere, constituting day-light.

Obs.—The solar rays pass freely through some solid and liquid bodies, hence called transparent, such as glass, rock-crystal, water, and many others, which, if clear and in moderately thin layers, intercept a portion of light that is quite inappreciable when compared to the quantity transmitted. Opaque bodies, on the contrary, intercept the rays entirely, absorbing some of them, and reflecting others. In this respect, also, there is a close analogy between light and caloric—for every good reflector of the one will also reflect the other. And though transparent bodies permit the light to pass through them, they nevertheless exert considerable influence upon it during its passage ; all the rays which fall obliquely being refracted, that is, they are made to deviate from their original direction. It was this property of transparent media which enabled Sir Isaac Newton to discover the compound nature of the solar light, and to resolve it into its constituent parts, by means of a triangular piece of glass, called the prism, the action of which depends upon the different degrees of frangibility of the seven coloured rays which compose a colourless one. The violet ray suffers the greatest refraction, and the red the least ; while the other colours of the rainbow lie between them, disposed in regular succession, according to the degree of deviation which they have individually experienced. The coloured figure thus produced is called the *prismatic spectrum*, which is always bounded by the violet ray on one side, and by the red on the other.

Sir Isaac Newton described light to be a substance consisting of small particles, constantly separating some luminous bodies, moving in straight lines, and rendering both bodies luminous by passing from them and entering the eye.*

Q. Is the solar light capable of producing any powerful chemical changes?†

A. It is so; and one of the most striking instances of this, is its power of darkening the white muriate of silver, which takes place slowly in the diffused light of the day, but in the course of a minute or two by exposure to the rays of the sun.

Mem.—It appears from the observation of Mitter and Wolfaston, that the effect thus produced is owing to the presence of certain rays that excite neither heat nor light, and which, from their peculiar agency, are termed chemical rays.

Q. What other changes do the rays of the sun produce?

A. The more refrangible rays of light possess the property of rendering steel or iron magnetic.

Obs.—The magnetic property of the solar rays was discovered in the violet ray by Dr. Morichini, of Rome; but as some eminent experimenters had repeated the experiments without success, the truth was involved in some degree of uncertainty. The fact, however, has been established by Mrs. Somerville, of London who, recently, laid her researches before the Royal Society. Sewing needles were rendered magnetic by exposure for two hours to the violet ray; and the magnetic property was

* Those who wish to become further acquainted with all the known properties of light, such as the refraction, inflection, &c., of its rays, may consult Newton's Optics, Fourcroy's System of Chemical Knowledge, and other papers by Herschel and Count Rumford, in the Philosophical Transactions.

Light is decomposable, by means of the prism, into seven distinct rays or colours.

communicated in a shorter space of time when the violet rays were concentrated by a lens. The indigo rays possess the magnetising power almost to the same extent as the violet; and the blue and green possess the same power, though in a less degree. Needles are also rendered magnetic by the sun's rays, transmitted through green and blue glass.

Light has great effect on vegetation. It also possesses the power of de-oxidizing (depriving a body of its oxygen) several of the metallic oxides, by combining with their oxygen, to which it gives wing, as it were, to fly off from the gas. Many animals and insects have the property of absorbing light and giving it out at pleasure; *e. g.* the glow-worm, the lightning-bug (of the United States), the fire-fly in the West Indies, and mention is made in the Annual Register (1802), of a sparrow in Hindostan that has the instinct to light up its nest in the night time with glow-worms, which it collects for this purpose, and attaches them to the inside of its nest by means of a tenacious clay.

ARTIFICIAL LIGHT.—Q. How are artificial lights procured?

A. By the combustion or burning of inflammable matter; or it is emitted by substances when strongly heated; also by friction, or collision of one substance with another.

Q. What is the cause of this emission of light from substances strongly heated?

A. A considerable accumulation of caloric.

Q. What is this shining or glowing appearance of a heated substance called?

A. Incandescence.

Q. At what temperature do solids generally begin to shine in the dark?

A. The temperature at which solids begin to shine in the dark is between 600° and 700° of F.; but they do not appear luminous in broad day till they are heated to about 1000° F.

Q. Does the caloric of incandescent bodies vary with the intensity of heat?

A. Yes: the first degree of incandescence, or *luminousness*, is an obscure red. As the heat increases, this redness becomes more and more vivid, till at last it acquires a full red glow. And, should the temperature still continue to augment, the character of the glow changes, and by degrees becomes white, shining with increasing brilliancy as the intensity of the heat augments.

Obs.—Liquids and gases likewise become incandescent when strongly heated; but a very high temperature is requisite to make a gas luminous, more, indeed, than is sufficient for heating a solid body even to whiteness. The different kinds of flame, as that of the common fire, candles and gas-lights, are instances of incandescent gaseous matter. So large a quantity of caloric is evolved during the process of combustion that the body is made incandescent at the time of being consumed. Those substances are preferred for the purposes of illumination that yield gaseous products when strongly heated, which, by becoming luminous while they burn, constitute flame. The light derived from such sources differ from the solar light in being accompanied by the radiant caloric similar to that emitted by a non-luminous heated body. The free radiant caloric may be separated by a screen of moderately thick glass; but the light so purified still heats any body that absorbs it, whence it would appear that it retains some calorific rays which, like those in the solar beam, accompany the luminous ones in their passage through solid transparent media. (*Powell, in Phil. Trans. 1825.*)

PHOSPHORESCENCE.—**Q.** What is phosphorescence?

A. Phosphorescence is a light emitted by some substances at common temperatures, and which gives rise to an appearance thus called. This phenomena seems owing, in some instances, to a direct absorption of light which is afterwards slowly emitted.

Exp.—A composition made by heating to redness a mixture of calcined oyster shells and sulphur, known by the name of Canton's phosphorus, possesses this property in a very remarkable degree. It shines so strongly for a few minutes after exposure to the light, that when removed to a dark room the hour on a watch may be distinctly noticed by it. After some time it ceases to be luminous, but it regains the property when exposed during a short interval to light. No chemical change attends the phenomenon.

Another species of phosphorescence is observable in some bodies when they are strongly heated. A piece of marble, for instance, heated to a degree which would make other bodies red, emits a brilliant white light of such intensity that the eye cannot support the impression of it.

A third species of this singular emission of light is observed in the bodies of some animals, either in the dead or living state. Some marine animals, and particularly fish, possess it in a remarkable degree. It may be witnessed in the body of the herring, which begins to phosphoresce a day or two after death, and before any variable sign of putrefaction has set in. Sea water is capable of dissolving the luminous matter; and it is probably from this cause that the waters of the ocean sometimes appear luminous at night when agitated. This appearance is also ascribed to the pressure of certain animalcules which, like the glow-worm or fire-fly, are naturally phosphorescent.

Q. What is the name of the instrument used to measure comparative intensities of light?

A. A photometer: the only one employed for estimating the relative strength of the sun's light is that of Mr. Leslie.

Q. Describe Mr. Leslie's photometer.

A. It consists of his differential thermometer, with one ball made of black glass. The clear ball transmits all the luminous rays that fall upon it, and therefore its temperature is not effected by them all; they are all absorbed, on the contrary, by the black ball, and by heating and expanding the air within it, cause the liquid to ascend in the opposite stem. The whole instrument is covered with a thin case of glass, the object of which is to prevent the balls from being affected by currents of cold air. The action of this photometer depends on heat produced by the absorption of light.

Obs.—Mr. Leslie conceives that light, when absorbed, is converted into heat; but according to the experiments already referred to, the effect must be attributed, not so much to the light itself, as to the absorption of the calorific rays which accompany it. Mr. Leslie's photometer is also recommended to determine relative intensities of artificial light, such as that emitted by candles, oil, or gas.

A second kind of photometer, invented by Count Romford, is on a totally different principle. It determines the comparative strength of lights by a comparison of their shadows; and is susceptible of great accuracy when employed with the requisite care; * but like the foregoing, its indications cannot be trusted when there is much difference in the colour of the lights.

* See an Essay on the Construction of Coal Gas Burners, in the Edinb. Philos. Journ. for 1825.

CHAPTER VI.

ELECTRICITY.

Q. WHAT have you to say with regard to Electricity?

A. Electricity is now very generally regarded, like the other imponderables, as a highly subtle elastic fluid, too light to affect our most delicate balances, moving with inconceivable velocity, and present in all bodies. It is one of the most active principles in nature. It is the cause of thunder and lightning; the phenomena of galvanism, and probably of magnetism are produced by it; and it exerts such an influence over chemical changes, as to have given plausibility to the notion that it is the cause of them.

Q. How may electricity be excited?

A. It may be excited in all solid substances by friction?

Q. How do you account for this assertion, which, at first view, seems contrary to fact?

A. It is well known that a metallic substance, if held in the hand, may be rubbed for any length of time without exhibiting the least sign of electricity, an observation which led to the division of bodies into such as may be excited by friction, and unto those which give no sign of excitement under similar circumstances; the former of which were called *electrics*, the latter *non-electrics*. This distinction, however, is not

founded in nature. A metallic substance does not indeed exhibit any trace of electricity when rubbed in the same way as a piece of glass; but if, while it is rubbed on the dry fur of a cat, it is supported with a glass handle, it will be found to attract light bodies near it (see *Exp.* p. 59).

Obs.—The difficulty and apparent impossibility of exciting metallic bodies, receives an explanation from the following facts:—it has been observed by philosophers, that the electric fluid passes with great facility over the surface of some substances, and with difficulty over that of others; hence they have been led to divide bodies into conductors and non-conductors of electricity.

Q. What substances belong to the class of electrical conductors?

A. To this class belong the metals, charcoal, plumbago, water, and most substances which contain water in its liquid state, such as animals and plants.

Q. What are those which belong to the list of non-conductors of electricity?

A. To this description belong glass, resin, sulphur, the diamond, dried wood, precious stones, silk, hair, and wool. Atmospheric air is also a non-conductor; were it not so, no substance could retain its electricity when surrounded by it. Aqueous vapours suspended in the air injure the non-conducting properties of the latter, and hence electrical experiments do not succeed so well when the air is charged with moisture as when it is dry.

Obs. The pressure of a little moisture communicates conducting properties to the worst non-conductor, and hence it is impossible to excite glass by rubbing it with a moist substance.

Q. Is friction the only exciter of electricity?

A. No: the electric fluid is often disturbed by chemical action, or by the mere contact of two substances of a different kind, as when a plate of zinc is made to touch a plate of copper. The same body is sometimes excited by different parts of it being unequally heated. Electricity is developed during various natural processes on evaporation, and the condensation of vapour, which may assist in accounting for certain electrical phenomena of the atmosphere.

Q. Are there any other causes of excitement by which electricity may be produced?

A. Yes: proximity to an electrified body, which has a tendency to induce an electric state opposite to its own.

Q. Give us an instance?

A. An excited stick of sealing wax attracts light bodies in its vicinity, because, being itself negative, it occasions them to be positively electrified. When the inside of a glass bottle is rendered positive by contact with the prime conductor of the electrical machine, the outside of it, if in communication with the earth, becomes negative.

Obs.—On this last depends the construction of the Leyden phial, which is merely a glass bottle or jar, coated to within three or four inches of the top, both internally and externally, with tinfoil. The aperture is closed by some non-conducting substance, through the centre of which passes a metallic rod that communicates with the tinfoil in the inside of the jar. The phial is charged by holding the outside of it in the hand, or placing it on the ground, while the metallic rod is made to receive sparks from the prime conductor. If in this charged state, the two surfaces are made to communicate by means of some conductor, the elastic equilibrium will be instantly

restored. An electrical battery is composed of a series of Leyden phials communicating with one another. The battery is charged and discharged in the same manner as a single phial.

Q. How is the electrical machine constructed?

A. The electrical machine consists of a large cylinder, or plate of glass, which is made to revolve by means of a handle, and is pressed during its rotation by cushions stuffed with hair, so as to produce considerable friction. The positive electricity excited on the glass is conducted away by insulated bars of brass or other metal, called the prime conductor, where it is collected in considerable quantity. The advantage of this arrangement is, that the electricity spread over the whole surface of the prime conductor, passes at once to any substance which touches one point of it.

Q. How many kinds of electricity are there?

A. Two: positive and negative; the first corresponds to the vitreous, the second to the resinous electricity of Dufay.

Obs.—The phenomena of electricity admit of being explained by both of these theories; but that of Dr. Franklin is commonly preferred in this country.

Q. How do you know when any substance is electrically excited, as well as the kind of electricity which it possesses?

A. By a knowledge of the electrical attractions and repulsions: for instance, a body is known to be in an excited state by its power of attracting light substances, or by causing two pith balls, suspended by silken threads, to repel one another when brought in contact with them.

Q. How may the strength of electricity be estimated?

A. The strength of electricity may be estimated by the extent of the divergence.

Obs.—Instruments for ascertaining the extent of the divergence of electricity are called Electrosopes and Electrometers; and one of the most efficient for this purpose, is that invented by Mr. Bennet, which is made of two slips of gold leaf, and is hence called the gold leaf electrometer.

Exp.—If a pith ball, suspended by a silken thread, is rendered positive by being touched with an excited stick of glass, it will of course be repelled* by presenting a positively electrified body to it; and, on the contrary, it will attract by one which is negative. In this way the kind of electricity may be determined.

CHAPTER VII.

GALVANISM.

Q. WHAT are the circumstances to which we are indebted for the name and origin of the science of Galvanism?

A. To experiments made on animal irritability by Galvani, about the year 1791.

Obs.—In the course of his investigations, Galvani discovered the fact, that muscular contractions are excited in the leg of a frog recently killed, when two metals, such as zinc and silver, one of which touches the crural nerve, and the other muscles to which it is distributed are brought into contact with one another. He imagined that the phenomena thus produced were owing to electricity present in the muscles, and

* For attraction and repulsion, see Affinity, &c.

that the metals only served the presence of a conductor : also, that animal electricity originated in the brain, was distributed to every part of the system, and resided particularly in the muscles. He was of opinion that the different parts of each muscular fibril were in opposite states of electrical excitement, like the two surfaces of a charged Leyden phial, and that contractions took place whenever the electric equilibrium was restored. This he supposed to be effected during life through the medium of the nerves, and in his experiments by the intervention of metallic conductors.

Q. Did these views of Galvani meet with any opponents ?

A. Yes, with several ; one of whom, the celebrated Volta, succeeded in pointing out their fallacy. He maintained that electricity was excited by the contact of the metals ; that the animal substances merely acted as conductors in restoring the electric equilibrium at the moment of its being distributed ; and that the contraction was produced by the stimulus arising from the passage of electricity along the nerves and muscular fibres. And to prove that electricity was excited in the manner he supposed, he brought plates of different metals, as zinc and silver, in contact with one another, and examined their electrical state, at the moment of separation, by means of a delicate electrometer—for which purpose it was found necessary to insulate each of the metallic discs, by supporting them on a handle of glass or resin. By this precaution, it was found that both the metals were excited, the silver negatively, and the zinc positively.

Q. As the quantity of electricity produced by any two metals is small, what means did Volta adopt to increase the effect ?

A. By employing several pairs of metals,

which he connected in such a manner that the electricity excited by each pair should be diffused throughout the whole series—an attempt which led him to the construction of the Voltaic pile.—(See a description of it in *Phil. Trans.*, 1800.)

Q. Of what does the voltaic pile consist?

A. It consists of any number of pairs of zinc and copper, or zinc and silver plates, each pair being separated from the adjoining ones by pieces of cloth, nearly of the same size as the plates, and moistened in a saturated solution of salt. The relative position of the metals must be the same in the whole series—namely, if the copper be placed below the zinc in the first combination, the same order must be preserved in all the others. The pile is contained in a proper frame, formed of glass pillars, fixed into a piece of thick wood which both supports and insulates it.

Obs.—The voltaic pile is now rarely employed, because we possess other modes of forming galvanic combinations of a more powerful and convenient description.

Q. What other means are employed in the formation of galvanic combinations?

A. The galvanic battery proposed by Mr. Cruikshank, which consists of a trough of baked wood, about thirty inches long, in which are placed, at equal distances, fifty pairs of zinc and copper plates previously soldered together, and so arranged that the same metal shall always be on the same side. Each pair is fixed in a groove cut in the sides and bottom of the box, the points of junction being made water-tight by cement.

Obs.—The apparatus thus constructed is always ready for

use, and is brought into action by filling the cells left between the pairs of plates with some convenient solution, which serves the same purpose as the moistened cloth in the pile of Volta.

Other modes now in use to facilitate the employment and increase the energy of galvanism, are the trough, made either of baked wood or glazed earthenware, divided into partitions of the same material, &c. The largest battery ever constructed is that of Mr. Children, described in the same paper. The great battery of the Royal Institution is composed of 2000 pairs of plates, each plate having 32 square inches of surface. It was by this that Sir Humphrey Davy was enabled to effect the decomposition and determine the constitution of the alkalies, on a discovery which at once extended as much the boundaries of chemical science, as it conferred honour on the discoverer.

The action of the galvanic trough is always attended by chemical changes between the liquid of the cells and one of the metals with which it is in contact.

In constructing a galvanic battery, each member of the series must consist either of one imperfect and two perfect conductors, or of one perfect and two imperfect. Among the good or perfect conductors are the metals and charcoal. The imperfect conductors are water, and saline or acid solutions.

Table of some Electrical Arrangements which, by Combination, from Voltaic Batteries, are composed of two Conductors, and one imperfect Conductor.

Zinc Iron Tin Lead Copper Silver Gold Platina Charcoal	Each of these is the positive pole to all the metals below it, and negative with respect to the metals above it in the column.	Solutions of Nitric Acid. Murratic Acid. Sulphuric Acid. Sal Ammoniac. Nitre. Other Neutral Salts.
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*Table of one Conductor, and two imperfect Conductors. **

Solution of Sulphur & Potash " Potash " Soda	Copper- Silver Lead Tin Zinc Other Metals Charcoal	Nitric Acid Sulphuric Acid Muriatic Acid Any other Solutions containing Acid.
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Obs.—In all combinations in which the fluids act chemically by affording oxygen, the positive pole is always attached to the metal which has the strongest affinity for oxygen; and in all combinations in which one metal is concerned, the surface opposite to the acid is negative, and that in contact with the solution of alkali and sulphur, or of alkali, is positive.

The more remarkable effects which the galvanic battery is capable of producing may be considered conveniently under four heads: 1st.

* These tables are taken from Sir H. Davy's Elements of Chemical Philosophy, and contain some series of perfect and imperfect conductors.

Its electrical phenomena. 2d. Its chemical agency. 3d. Its power of igniting the metals; and 4th. Its action on the magnet.

Dr. Wollaston (*Phil. Tr.* for 1801) has shewn that all the chemical effects of the galvanic battery may be produced by electricity, as well as all the common electrical experiments by means of galvanism.

THEORY OF THE GALVANIC PILE.—There are three theories concerning the action of the voltaic pile or battery. Volta, with whom the first originated, in forming his theory, left out of view the chemical changes going on between the metals and the fluids in contact with them; whereas it was apparent that these changes constituted an important, if not an essential, part of the process. For it was observed that no sensible effects were produced by a combination formed of substances which have no chemical action on each other; that the action of the pile is always accompanied by the oxidation of the zinc; and that its energy is almost in exact proportion to the rapidity with which the oxidation takes place. It was these observations which induced Dr. Wollaston to conclude that the process begins with the oxidation of the zinc—that the oxidation is the primary cause of the electric phenomena—an opinion, in support of which he published several ingenious experiments in the *Philosophical Transactions* for 1801. This forms the second theory of the pile, and is in direct opposition to that of Volta.

The third theory, or that proposed by Sir H. Davy, is intermediate between the two preceding. In this, it was inferred, from numerous

experiments, that there is no reason to question the fact, originally stated by Volta (see p. 60), that the electric equilibrium is disturbed by the contact of different substances without any chemical action taking place between them; and his conclusions appear to be justified by subsequent observers. But he perceived, at the same time, that the chemical changes, though not the primary cause of the phenomena, are an essential part of the process; that without them no considerable degree of galvanic excitement can ever be produced. In the opinion, therefore, of Sir H. Davy, the action is commenced by the contact of the metals, and kept up by the chemical phenomena.

CHAPTER VIII.

ALKALIES.*

Q. WHAT is the nature of an alkali?

A. The alkalies have an acrid and urinous taste; they change the blue juices of vegetables to a green colour, and the yellow to a brown;† and have the property of rendering oils durable with water. They are incombustible, but may be rendered volatile by great heat. They are

* The word alkali is of Arabian origin, and signifies the dregs of bitterness.

† Although this effect of alkalies on the blue juices of vegetables is almost universal, we know of one exception; namely, tincture of litmus, and litmus paper, are always rendered more intensely blue, by the addition of alkalies.

soluble in water, form various salts by combination with acids;* and act as powerful caustics when applied to the flesh of animals.

Obs.—It seems that the causticity of alkalis depends on chemical affinity, and that the caustic substance corrodes the matter to which it is applied, in consequence of its tendency to unite with that matter; and that it continues to act upon it until it has saturated itself by the combination.

Exp.—If a piece of animal flesh be put into a strong solution of potass or soda, it will immediately be acted upon by the alkali, and soon be entirely dissolved.

Q. How many alkalis are there?

A. Three; two of which have been called *fixed*, and the other the volatile alkali.

Q. Which are the fixed alkalis?

A. Potass† and soda are called the fixed alkalis, because they will endure a great heat, and still remain unchanged.

Q. What are the alkalis composed of?

A. Till latterly the fixed alkalis were considered to be *simple* substances, in consequence of chemists not having been able to decompose them; but they are now found to be compound bodies.‡

Q. How is potass procured?

A. It is chiefly procured by lixiviation from the ashes of burnt wood, and other vegetable substances; but as it exists in minerals and

* Potass becomes comparatively mild by its union with carbonic acid; and the most caustic soda, if united to corrosive muriatic acid, forms the mild salt used at our tables.

† Modern chemists call the pure vegetable alkali *potass*, whereas the article of commerce is called *potash*. Soda takes its name from the *Salcola* plant, which grows on the Spanish coast, where it is burnt for its preparation.

‡ The late galvanic experiments of Sir H. Davy have confirmed the truth of this conjecture, and proved, beyond all doubt, that potass and soda are both metallic oxides.

earths; there is reason to believe that plants receive it from the earth during vegetation: hence it may be proper to entirely discard the word *vegetable* when speaking of this substance.

Q. From what substances is soda derived?

A. From the ashes of *marine* plants; but its great depository is the ocean, soda being the base of sea-salt, or muriate of soda.

Obs.—Potass* was called the vegetable alkali, because it was supposed to exist only in vegetables, though it is now found in some minerals. Soda was called mineral alkali, because it exists in mineral salts; although it is also procured by chemical process from sea-salt, which is found in numerous masses under the earth's surface in many countries, particularly in Poland, Hungary, Spain and England.

Q. How do you account for marine plants giving out soda; while those which grow in the interior of the country afford potass?

A. This can only be accounted for by supposing that vegetables have the power, during vegetation, of decomposing sea-salt, and retaining the soda in their constitution.

Q. In what other state is soda to be met with?

A. It is likewise found in great plenty combined with carbonic acid in the native beds of Egypt, and in the West Indies; it also occurs in various other parts of the world, though never in a state of purity.

Q. What are the distinguishing properties of these two alkalies?

A. The fixed alkalies are very similar in their general properties; but are easily distinguished by the variety of salts which they form with the

* This alkali was formerly procured by burning vegetables in large iron pots—hence it acquired the name of *potash*.

acid; and by potass being more deliquescent than soda.

Q. By what chemical test can you distinguish these two alkalies?

A. There are many tests by which these alkalies may be distinguished: put a solution of the one of platina in nitro-muriatic, and it will answer this purpose most completely.

Q. What are the principal uses of these alkalies?

A. The fixed alkalies have various uses in surgery and medicine; they form the bases of several salts; are employed much in the arts; and are of great importance to the analytical chemist.

Obs.—The greatest consumption of the fixed alkalies in this country is in the manufacture of soap. They are also largely employed in bleaching, and in the manufacture of glass. Soda has the property of fusing silex of which glass is made, with more facility than potass. The alkalies are also employed to facilitate the extraction of the colouring matter from a few of the foreign woods, and in some processes to precipitate the colours from metallic salts.

In most of the manufactures soda is preferred to potash, because it is much less acrid, and does not attack or weaken the texture of linen goods, nor corrode and destroy utensils of wood, metal, &c., as potash does.

Without an alkali, many of the colours manufactured in this country could not be made: for instance, animal matters are always incinerated with an alkali to form Prussian blue; or fixed alkali is also employed as a flux in the formation of the potter's blue from cobalt; and what are called French and mineral green are made by precipitating copper from its solutions

by means of these alkalies. They are also employed in making alum; in bleaching linen, scouring wool, and in many other processes too various to be enumerated.

Q. From what part of the world is this country supplied with these articles?

A. The greatest part of the potash used in this country comes from America and Russia; but the kelp of our own coasts and the barilla of Spain, and of the islands of Teneriffe and Sicily; furnish us with the greatest portion of our mineral alkali.

Q. Are these articles sold in a state of purity?

A. No: both potash and soda always contain carbonic acid and water; and are often contaminated with earths, sulphur, and other impurities.*

Q. Have alkalies any peculiar affinity for sulphur?

A. Both potash and soda, as well as ammonia, have a strong affinity for sulphur; they combine by trituration or heat, and form sulphuret of alkali, formerly called "liver of sulphur."

Exp.—If equal parts of sulphur and pure potash be triturated together in a mortar, the sulphur will soon acquire a green colour, the temperature of the mixture will be raised, and a *sulphurate of potash* formed. Carbonate of soda or potash will answer for this purpose as well as the pure alkali, if heat be employed.

Q. What are the properties of sulphuret of alkali?

* The ash, which contains twenty per cent. of pure alkali, is capable of taking up fifteen parts of sulphur. Such ashes may be desulphurated three ways. 1. By calcining them in an open furnace, exposed to a rapid blast of air; 2. By saturating them with any vegetable acid; 3. And by exposing them in a situation to imbibe carbonic acid. (See *Phil. Trans.* for 1789.)

A. In colour it resembles that of the liver of animals; its taste is acrid and bitter, and it has the property of decomposing water.

Q. How are the alkalies of commerce purified for use?

- *A.* In order to purify potash or soda, it is generally mixed with a portion of quick lime, to divest it of its carbonic acid, and then lexivated in proper vessels to obtain a solution of the caustic alkali, free from other impurities. When it is required perfectly pure for nice purposes, the alkali is dissolved in alcohol, and purified by a similar process.* (See *Thomson's Notes on Fourcroy*, vol. i. p. 373; also, *Lowitz on Nicholson's Journal*, vol. i. 4.)

Q. Are the fixed alkalies ever used in a state of combination with carbonic acid?

A. Carbonic acid gives potash and soda the property of crystallizing readily; it also renders them mild, and fit for purposes in which caustic alkali would be improper; hence carbonate of potash is employed in medicine, and carbonate of soda for washing and other domestic uses.

Obs.—Dr. Henry has suggested that the fixed alkalies may be purified from sulphate of potash, which generally contaminates them, by means of barytes, by rendering the alkali perfectly caustic by quick lime, and then adding to the clear solution a warm solution of pure barytes earth till the precipitation ceases. The barytes seizes the sulphuric acid, and leaves the alkali pure; which may be afterwards saturated with carbonic acid. During its restoration to a mild state, any barytes that may remain in excess is precipitated.

Carbonate of soda and carbonate of potash.

* Sir H. Davy has shewn the potash obtained by alcohol is not a pure alkali, as has been imagined, but a compound of potash and water, containing between seventeen and eighteen of the latter.

are of use in chemical laboratories as *re-agents*, being employed for purposes which could not be effected by the *caustic* alkalies. Thus the two fixed alkaline carbonates will precipitate barytes, strontian, lime, magnesia, manganese, and iron from their solutions, by means of double affinity. But when these re-agents are employed to precipitate either of the three latter substances, if too much be used, the precipitate will be *re-dissolved*: some surety therefore is requisite in separating magnesia, manganese, and iron by this means from their solutions.

Q. What is the name of the volatile alkali, and its properties?

A. It is called ammonia: it is urinous and caustic; but it does not, like potass and soda, corrode animal substances. Its most simple state is that of gas, which is lighter than atmospheric air in the proportion of 3 to 5; and, like it, it is elastic and invisible, but it causes the death of animals that are obliged to breathe it. In some of its combinations it is so extremely volatile that it will bear no degree of heat without being dissipated. It has another peculiar property, that of reducing the oxides of metals to a metallic state. Ammonia being composed of hydrogen and nitrogen, the hydrogen seizes the oxygen from the metal, and forms water, while the nitrogen escapes in a gaseous form. Some metals are oxidized and dissolved in liquid ammonia.

Q. As this alkali is a gaseous substance, how has it ever been used in the arts.

A. Ammonia has an affinity for water, with which it readily combines, and forms *liquid ammonia*, in which state it is generally used.

Obs.—It is owing to the levity of ammonia that water becomes specifically lighter in proportion to the quantity of gas it contains. Next to hydrogen, and carburetted hydrogen, ammonia is the lightest of all the gaseous bodies. Its specific gravity compared with hydrogen is as eight to one. One hundred cubical inches of it weigh about eighteen grains.

Q. What is the composition of ammonia?

A. Ammonia is composed of hydrogen and nitrogen, in the proportion of about two parts of the former and eight of the latter.

Obs.—One thousand parts of ammonia consist of eight hundred and seven parts of nitrogen and one hundred and ninety-three parts of hydrogen. This is the result of experiment; but Sir Humphrey Davy has, by means of galvanism, separated a peculiar substance of a metallic nature from ammonia.

Exp.—Take some filings of tin or zinc, pour on them some moderately dilute nitrous acid. After a short time stir into the mixture some quick lime, or caustic alkali, and a very strong pungent smell of ammonia will be produced.

Q. Is ammonia capable of being decomposed?

A. Yes: it may be decomposed by the electric spark. Oxygen gas will also decompose it by the assistance of heat, and the nitrous acid and water will be the result. If passed over red hot charcoal, it will combine with part of the charcoal, and form *prussic acid*.

Exp.—To shew the decomposition of ammonia, fill four-fifths of a long glass tube with strong oxygenized muriatic acid, and the remaining fifth with water strongly impregnated with ammonia, and invert it in a saucer of water. When the tube is inverted, the ammonia, on account of its lightness, will pass through the oxygenized muriatic acid; but by its passing, a strong effervescence is produced, and a decomposition ensues. When the effervescence has ceased, a portion of nitrogen gas will be found in the tube.

Q. What is the effect of galvanism on ammonia?

A. If ammonia be decomposed in contact with mercury, a very different result may be obtained by means of galvanism; for, in this case, a metallic substance of a very uncommon nature may be extracted from the alkali.

Obs.—Mercury in combination with about one-twelve-thousandth part of its weight of new matter, is rendered a solid, and at the same time so expanded in volume that its specific gravity is reduced from 13.6 to less than 3; while all its metallic characters of colour, lustre, opacity, and conducting power, remain unimpaired.

Q. How is ammonia procured?

A. From all animal and vegetable substances in a state of putrefaction. In England, however, it is generally procured by a dry distillation of bones, horns, and other animal substances. It is also found in mineral waters. According to Dr. Austin, ammonia is formed whenever iron rusts in water which has a free communication with the air.

Obs.—For chemical experiments ammoniacal gas may be procured as follows:—Mix one part of powdered sal-ammonia with two parts of powdered quick lime in a retort, and apply the heat of a lamp, which will disengage the gas in abundance. On account of its affinity for water, this gas must be received over mercury.

Ammoniacal gas may also be procured by heating strong liquid ammonia, and collecting the gas as before.

Muriatic or acetic acid are the usual tests employed to discover the presence of ammonia. If either of these be held over any thing evolving ammonia, white fumes will appear, which are

owing to the ammonia uniting with the acid, and forming a visible cloud, which is a true neutral salt in vapour.

Q. What are the uses of ammonia?

A. In a liquid state, ammonia has various uses in our manufactures, and in medicine; it is a valuable re-agent to the chemist, and when combined with carbonic acid it takes a concrete form and a beautiful white colour, being then the article known in commerce by the name of volatile salts. It is also serviceable in dying and in staining ivory; but its principal use is in making the muriate of ammonia, of which it is the basis. In tinning metals it is of use, to cleanse the surfaces, and to prevent them from oxydizing by the heat which is given to them in the operation. This salt is also employed in the assay of metals to discover the presence of iron.

Q. How is ammonia formed into muriate of ammonia?

A. By combining ammonia with muriatic acid.

Q. Muriate of ammonia being formed by two gaseous substances, how does it acquire a solid form?

A. The bases of these gases having a greater affinity for each other than they have for caloric, they combine intimately whenever they come in contact; and the compound having less occasion for caloric than the separate ingredients, the caloric is given out, and a solid is produced.

Obs.—This mixture may be considered one of the most striking chemical combinations with which we are acquainted. Ammoniacal gas, and muriatic acid gas, are two of the most pungent and volatile substances known; they are so volatile and gaseous that when in a state of purity neither of them can

be condensed; and yet these gases are no sooner thrown together than they form a solid and inodorous substance, void of volatility, and of little taste.

Q. From whence was sal-ammoniac procured before it began to be made in this country?

A. Sal-ammoniac was formerly brought from Egypt; but it is now made in various parts of Great Britain, particularly in Scotland, where it is formed by a peculiar process from soot.

Q. Is ammonia capable of entering into any other combinations?

A. Yes; ammonia is capable of forming salts with most, if not all the acids.

Obs.—If ammoniacal gas be brought into contact with either of the acid gases, both lose their aeriform appearance, and a solid salt is produced. These salts are called ammoniacal salts. (See *Salts*.)

CHAPTER IX.

THE VEGETABLE ALKALIES.

THE honour of discovering this class of alkalies is due to Sertuerner, a German apothecary. The chemists who have cultivated this department with success are M. Robiquet, and MM. Pelletier and Caventon.

According to Pelletier and Dumas, all the vegetable alkalies consist of carbon, hydrogen, oxygen, and nitrogen. They are easily decomposed by nitric acid, and by heat, and ammonia is always one of the products of the destructive

distillation. These alkalies, for the most part, are very insoluble in water, and sparingly so in cold alcohol; though they are readily dissolved by the latter at a boiling temperature, being deposited from the solution, commonly in the form of crystals on cooling. Most of the salts are far more soluble in water than the alkalies themselves. As the vegetable alkalies agree in several of their leading chemical properties, the mode of preparing one of them, admits with slight variation to all.

Mode of preparing the Vegetable Alkalies.—The substance containing the principle is digested, or more commonly macerated, in a large quantity of water, which dissolves the salt, the base of which is the vegetable alkali. On adding some more powerful salifiable base (potassa or ammonia), or boiling the solution for a few minutes with lime or pure magnesia, the vegetable alkali is separated from its acid, and being in that state insoluble in water, may be collected on a filter and washed. To purify it from the oleaginous, resinous, or colouring matter which it is apt to retain from the plant, after being thus procured, it should be mixed with a little animal charcoal and dissolved in boiling alcohol, and afterwards filtered while hot; the pure alkali is yielded, either on cooling or by evaporation; and if not quite colourless, it should again be subjected to the same action with animal charcoal.

Morphine.—This is the narcotic principle of opium, which contains a great diversity of different principles,—as morphia, meconic acid, narcotine, gummy resinous and extractive colouring matters, lignin, fixed oil, and a small quantity of caoutchouc. On infusing opium in

water, several of the above principles are dissolved, and especially the meconate of morphine, with narcotine, which is likewise rendered soluble by an acid.

Obs.—The best process for procuring pure morphine, which is white and crystallizes readily, in small rectangular prisms of a brilliant lustre. When pure, owing to its insolubility, it is almost inert. An overdose may be prevented by giving a dilute solution of ammonia, or an alkaline carbonate, so as to precipitate the vegetable alkali. When carefully administered, morphine may be very advantageously employed in the practice of medicine; since, according to Magendie, it produces the soothing effects of opium, without causing the feverish excitement and headache which so frequently accompany the latter. The form of the acetate is the best mode of exhibiting it.

Meconic Acid.—This was procured from the magnesian precipitate (the meconate of magnesia) obtained in procuring the acetate of morphea. It has a sour, followed by a bitter taste, reddens litmus paper, and is very soluble both in water and alcohol. It is characterized by giving a red colour to the salt of the peroxide of iron, and communicates an emerald green tint to the sulphate of copper. It exerts no action on the animal system.

Narcotine.—This substance, though not regarded as a vegetable alkali, is only noticed from its connection with morphine. It is easily prepared by evaporating an aqueous infusion of opium to the consistence of an extract, and digesting it in sulphuric ether.

Pure narcotine is insoluble in cold, and very slightly soluble in hot water. It dissolves in oil, ether, and alcohol. It does not possess any alkaline properties, though, by means of an acid, it is rendered soluble in water.

Obs.—The unpleasant stimulating properties of opium are attributed by Magendie to the presence of narcotine, the ill effects of which, according to his experiments, are in a great measure counteracted by acetic acid. Hence it is probable that the superiority assigned to the *black drop*, once the tincture or opium of the shops, is to be attributed to the vegetable acids which enter its composition.

CINCHONINE AND QUININE.

This distinct vegetable principle in the cinchona bark was inferred by Dr. Duncan, jun., in 1808, who ascribed to it the febrifuge virtues of the plant, and proposed for it the name of *cinchonin*.^{*} Afterwards, Dr. Gomez, of Lisbon, succeeded in procuring it in a separate state; but its alkaline nature was first discovered in 1820, by MM. Pelletier and Caventou, by whose labours it has been fully established that the febrifuge properties of the bark is possessed by two alkalies, the *cinchonin* of Dr. Duncan, and quinine, both of which are combined with kinic acid. Though very analogous, these principles are distinctly different, standing in the same relation to each other as potass and soda; the former exists in the *cinchona condaminea*, or pale bark; the latter is present in the *cinchona cordifolia*, or yellow bark; and they are both contained in the *cinchona oblongifolia*, or red bark.

Pure cinchonine is white and crystalline. It requires 2,300 times its weight of boiling water for solution, and is insoluble in cold water. Its proper menstruum is boiling alcohol; but it is dissolved in small quantity by oils and ether. Its

^{*} See Edinburgh New Dispensatory, 11th Ed. p. 299.

alkaline properties are exceedingly well marked, from its neutralizing the strongest acid.

Quinine was discovered by Pelletier and Caventou. It does not crystallize like cinchonine when precipitated from its solutions, but it has a white porous, and rather flocculent aspect. Its febrifuge virtues are more powerful than those of cinchonine, and it is now extensively employed in the practice of medicine. It is most commonly exhibited in the form of the sulphate, a salt of such activity that three grains have been known to cure an intermittent fever. It dissolves readily in strong alcohol by the aid of heat, a character which affords a useful test of its purity.

STRYCHNINE. BRUCINE.

MM. Pelletier and Caventou discovered strychnine in 1818, in the fruit of the *strychnos ignatia* and *strychnos nux vomica*. It has since been extracted by the same chemists from the upas. It is one of the most virulent poisons hitherto discovered, and is the poisonous principle of the substances which contain it. Its energy is so violent, that half a grain blown into the throat of a rabbit, occasioned death in the course of five minutes. Its operation is always accompanied with symptoms of locked jaw and other tetanic affections.

Brucine.—This alkali was also discovered by MM. Pelletier and Caventou, soon after their discovery of strychnine; it also exists in small quantity in the St. Ignatius' bean and the *nux vomica*. In its bitter taste and poisonous qualities it is very similar to strychnine, but is twelve or sixteen times less energetic.

VERATRINE, EMETINE, PICROTOXINE, SOLANINE,
DELPHINE, &c.

Veratrine.—It was discovered by Pelletier and Caventou, that the medicinal properties of the seeds of the *veratrum sabadilla*, and of the root of the *veratrum album* or white hellebore, and of the *colchicum autumnale* or meadow saffron, are owing to the peculiar alkaline principle of veratrine, which may be extracted by the usual process. It exists in the above plants, in combination with gallic acid. It is white and pulverulent, inodorous, and of an acrid taste. When taken internally in very small doses, it produces extensive irritation of the mucous coat of the stomach and intestines; and a few grains were found to be fatal to the liver of animals. It is very soluble in alcohol. It requires one thousand times its own weight of boiling, and still more of cold water for its solution. It has an alkaline re-action and neutralizes acids, but it is a weaker base than morphine, quinine, or strychnine.

Emetine.—A new principle discovered in 1817, by M. Pelletier, in the several species of ipecacuanha. It is a white pulverulent substance, of rather a bitter and disagreeable taste; sparingly soluble in cold but more freely in hot water, and insoluble in ether; but readily dissolved by alcohol. It has a distinct alkaline re-action, and neutralizes acids; but its salts are little disposed to crystallize.

Picrotoxine.—This alkali, the bitter poisonous principle of the *cocculus Indicus*, was discovered in 1819, by M. Boullay, who gave it the above name.

Solanine.—The active principle of the *solanum dulcamara* (woody nightshade), procured in a pure state by Desfosses. This compound has distinct alkaline properties, and is combined in the plant with malic acid.

Delphine.—Discovered by MM. Feneuille and Lassaigne in the *delphinium staphysagria*, or stavesacre. It possesses the general character of the vegetable alkalies.

Obs.—To the vegetable alkalies here described, may be added gentianine, discovered by MM. Henry and Caventou, in analysing gentian; lupuline, by Mr. Ives, of New York, from the *humulus lupulus*, or common hop; and it has been rendered highly probable, chiefly by the researches of M. Brandes, that several other plants, such as the *atropa belladonna* (deadly shade), *conium maculatum* (the spotted hemlock), *hyoscyamus niger* (black henbane), *datura stramonium* (thorn apples), and *digitalis* (foxglove), all owe their activity to the presence of an alkali.*

CHAPTER X.

ACIDS.

Most of the acids are substances which produce that sensation of the tongue called *sour*; but some substances are classed with the acids which have not this characteristic, though they possess some of the other properties of acids, which

* For a practical digested account of the recently discovered alkalies, or alkaloids, on the authority of M. Magendie, with formulæ, &c., see 'The New London Medical Pocket Book.' Sherwood & Co.

differ from each other in their appearance and properties as much as any classes of bodies we are acquainted with: it is therefore not a little difficult to give a definition of an acid. In general they are liquids, but some of them take a solid, and others a gaseous form; some are mild, others corrosive; some are pungent and volatile, others are fixed and inodorous.

Q. What are the properties of acids?

A. Acids change the blue, green, and purple juices of vegetables to red; and combine with alkalies, earths, or metallic oxides, so as to form those compounds called salts.

Q. What is the origin of acids?

A. Most of the acids owe their origin to the combination of certain substances with oxygen, which has been called the acidifying principle.

Obs.—The substances which are combined with oxygen to form acids (in all the decomposable acids,) *combustible* substances. Indéed, several of the acids are the product of combustion: witness the sulphuric, the phosphoric, &c. Four of the metals, and all the other simple combustibles, except hydrogen, are convertible into acids. All bodies, to which the properties of an acid have been ascribed, are either combustibles, supporters of combustion, or may be produced by the process of combustion. It is proper to remark that some of the acids are the productions of art, and are not known to exist in nature.

Q. How is it known that oxygen imparts acidity?

A. This is only known by analogy; for it is found that most of the acids contain oxygen, and that they lose their acidity exactly in proportion to the quantity of oxygen which is taken from them.

Obs.—Many of the acids may be decomposed, and deprived of the oxygen, by combustion. Any combustible body that

has a greater affinity for oxygen than oxygen has for the radical of the acid, will decompose that acid.

Q. By what other means may acids be decomposed?

A. Some acids may be decomposed, and deprived of their oxygen; and others may be formed by a direct combination of oxygen with certain radicals.

Obs.—This is shown by the composition of sulphuric acid, which, for experiment, may be formed as follows:—

Exp.—Mix a little sulphur coarsely powdered with one-eighth of its weight of ground nitre. Put the mixture upon a small tile, and place the tile upon a low stand in the middle of a large flat glass or earthen dish. Then pour a large quantity of water into the dish, and procure a large glass jar to invert over the brimstone, so that its edges may dip into the water, which must be deep enough to form a water lute. Things thus prepared, the brimstone is to be set on fire in several places, by means of a red hot iron, and immediately covered with the jar. The sulphur will burn with great rapidity; and will be chiefly converted into sulphuric acid, which may be concentrated by evaporating the superfluous water.

. In this process the sulphur unites with the oxygen of the atmospheric air within the jar, at the same time that the heat and light, which are necessary in the new compound, are evolved, and become sensible to our feelings: the result is a new substance, widely different from either, viz. sulphuric acid. The use of the water is to absorb the gas, and render it liquid.

Q. Do the same radicals* always combine with an equal portion of oxygen?

A. No: some of these acidifiable radicals

* A chemical term for the elements of bodies.

combine with different proportions of oxygen, and consequently produce different states of acidity.

Q. How do chemists distinguish this difference?

A. When two acids have the same radical, but contain different quantities of oxygen, they are distinguished by their termination. The name of that which contains the most oxygen ends in *ic*, the other *ous*. Thus we say *sulphuric* acid, and *sulphurous* acid; *phosphoric* and *phosphorous* acid.

NOMENCLATURE OF THE ACIDS AND SALTS.—

Compounds with which oxygen forms a part, were called acids or oxides, according as they do or do not possess acidity. An oxide of iron or copper signifies a combination of those metals with oxygen, which has no acid properties. The name of an acid was derived from the substance acidified by the oxygen, to which was added the termination in *ic*. Thus sulphuric and carbonic acids signify acid compounds of sulphur and carbon with oxygen gas. If sulphur or any other body should form two acids, that which contains the least quantity of oxygen is made to terminate in *ous*, as sulphurous acid. The termination in *uret* was intended to denote combinations of the simple non-metallic substances, either with one another, with a metal, or with a metallic oxide. For instance, *sulphuret* and *carburet* of iron, signify compounds of sulphur and carbon with iron. The different oxides or sulphurets of the same substance were distinguished from one another by some epithet, which was commonly derived from the colour of the compound, such as the black and red oxides of iron, the black and red sulphurets of

mercury. Though this practice is still continued occasionally, it is now more customary to distinguish degrees of oxidation by the use of derivatives from the Greek. *Protoxide* signifies the first degree of oxidation; *deutoxide* the second; *tritoxide* the third; and *peroxide* the highest. The sulphurets, carburets, &c., of the same substance are designated in a similar way. The combination of acids with alkalis, earths or metallic oxides, were termed salts, the names of which were so contrived as to indicate the substances contained in them. If the acidified substance contains a maximum of oxygen, the name of the salt terminates in *ate*; if a minimum, the termination in *ite* is employed. Thus the sulphate, phosphate, and arseniate of potass, are salts of sulphuric, phosphoric, and arsenic acids; while the terms sulphite, phosphite, and arsenite of potass, denote combinations of that alkali with the sulphurous, phosphorous, and arsenious acids.

Q. Have acids ever any other degree of acidity?

A. Attempts have been frequently made to supersaturate several of the acids with oxygen, but only in one instance with success, namely, in the muriatic acid, which forms with two different portions of oxygen two other distinct acids, called oxygenized muriatic acid, and hyper-oxygenized muriatic acid.

Q. What substances are capable of being acidified by oxygen?

A. The mineral, the vegetable, and the animal kingdoms, all furnish bases or radicals, which become acid by their union with oxygen.

Obs.—The mineral acids are generally formed with a peculiar base and oxygen; the vegetable acids, with carbon, hydrogen and oxygen; while the animal acids are composed of the same substances united with nitrogen.

. Some of the mineral acids are decomposable by charcoal heated to redness. Some of the vegetable acids are also decomposed, and reduced into water and carbonic acid, by leaving them in an exposed situation to the action of their own principles: others may be changed into different acids, by imparting or abstracting a portion of oxygen. The animal acids are of all others the most liable to decomposition. In an elevated temperature, the carbon and oxygen unite to form carbonic acid, and the hydrogen and nitrogen produce volatile alkali.

Q. Do all the acids owe their acidity to the presence of oxygen?

A. The greater number of them do, but there are substances possessing acid properties which contain no oxygen. Until lately there were only three acids whose composition was unknown,—namely, the muriatic, the fluoric, and the boracic; these, however, have yielded to the power of Voltaic electricity, and their bases have been separated.

CLASSIFICATION OF ACIDS.

The acids were formerly divided into three classes,—namely, the mineral, the vegetable, and the animal acid; but the more useful and scientific way of dividing them is into two classes.

I. The undecomposable, and those which are formed with two principles, are comprised in the first class; while those acids which are

formed with more than two principles compose the second. Those of the first class, which are formed with two principles only, are composed of oxygen and some other substance, which is called their radical. The acids of the second class are composed chiefly of oxygen, hydrogen, and carbon; though some of them contain a portion of nitrogen.

The acids of the first class are,—The sulphuric and sulphurous acids; the muriatic and oxygenized muriatic acids; the nitric, the carbonic, the phosphoric and phosphorous; the fluoric, the boracic, arsenic, the tungstic, molybdic, and the chromic acids.

The acids of the second class are,—The acetic, the oxalic, the tartaric, the citric, the malic, the lactic, the gallic, the mucous, the benzoic, succinic, the camphoric, the suberic, the lactic, the prussic, the sebacic, the uric, the amniotic, and the fluoboric acids.

CHAPTER XI.

VEGETABLE ACIDS.

THOSE compounds are regarded as vegetable acids which possess the properties of an acid, and are derived from the vegetable kingdom, as those of the second class.

1. *Acetic Acid.* This acid exists already formed in the sap of many plants, either free or combined with lime or potass; it is generated

during the destructive distillation of vegetable matter, and in an abundant product of the acetous fermentation.

Common vinegar, the acidifying principle of which is the acetic, and is commonly prepared in this country by fermentation from an infusion of malt, and in France from the same process taking place in weak wine. The vinegar thus obtained is a very impure acetic acid, containing the saccharine, mucilaginous, and other matters existing in the fluid from which it is prepared. It is separated from these impurities by distillation; and is rendered stronger by exposure to cold.

Obs.—The distilled vinegar now generally employed for chemical purposes, is prepared by the distillation of wood, and is sold under the name of *pyroligneous acid*. Concentrated acetic acid is best obtained by decomposing the acetates either by sulphuric acid, or in some instances by heat. With various bases it forms salts; called the acetates.

2. *Oxalic Acid*. This acid exists ready formed in several plants, especially in the *rumex acetosa* or common sorrel, and in the *oxalis acetosella* or wood sorrel; but it almost always occurs in combination either with lime or potass. These plants contain the binoxalate of potass; and the oxalate of lime has been found in large quantity by M. Braconnot, in several species of lichen. It is easily made artificially by digesting sugar in five or six times its weight of nitric acid, and expelling the excess, and by distillation.

USE.—It is of great use in detecting the presence of lime in solution. It is also become an article of great consumption with the calico printers, both in the state of crystallized oxalic acid, and in that of super-oxalate of potass. In

combination with earth, alkalies, and metallic oxides, it forms the salts called *oxalates*.

Form.—It crystallizes in slender, flattened, quadrilateral prisms, terminated by two sided prisms; but their primary form is an oblique rhombic prism: by this form it is easily distinguished from all other acids; and by its solution giving with lime-water a white precipitate, which is insoluble in an excess of the acid.* It has an exceedingly sour taste, reddens litmus paper strongly, and forms neutral salts with alkalies. The crystals effloresce on exposure to the air, but undergo no other change. They are soluble in twice their own weight of cold air in their own weight of boiling water. They are also dissolved by alcohol, though less freely than in water.

3. *Tartaric Acid*. This is a peculiar acid, found in the cream of tartar of commerce. It is capable of crystallization, and easily soluble in water. It is used by calico printers to discharge false prints. The salts formed with it are called *tartrates*.

4. *Citric Acid*. This is found in the juice of lemons and several other fruits. It crystallizes in beautiful rhomboidal prisms; is extremely acid to the taste, and very soluble in water. It is used in various ways for domestic purposes, medicine, and the arts. The salts formed with it are called *citrates*.

5. *Malic Acid*. This is obtained from the juice of apples, in which it exists ready formed. It is

* The experiments of Mr. Christison and Coindet have shewn that chalk and magnesia are certain antidotes to poisoning by oxalic acid, in consequence of forming with it insoluble and inert compounds.

principally used as a chemical test. Its salts are called *malates*.

Obs.—Malic acid is of use in the analysis of earths, for separating alumine from magnesia, as it forms with the former an insoluble salt, which precipitates, leaving malate of magnesia in solution.

6. *Lactic Acid*. This is prepared from milk after the curd has been separated. It is incapable of crystallization, and has not hitherto come into use. The salts formed with it are called *lactates*.

7. *Gallic Acid*. This acid was discovered by Scheele, in 1786, and exists ready formed in the bark of many trees, and in gall nuts. It is always associated with tannin, a substance to which it is allied, in a manner hitherto unexplained. It has the property of precipitating iron from its solution in acids, of a black colour. Its salts are called *gallates*.

8. *Mucous or Saccolactic Acid*. This is obtained by nitric acid from gum Arabic, and other mucilaginous substances. It is in the form of a white gritty powder, with a slightly acid taste. Its salts are called *mucites*.

9. *Benzoic Acid*. This exists in gum Benzoin, in Storax, in the balsams of Peru and Tolu, and in several other vegetable substances. It is a light whitish powder, with a peculiar and aromatic odour. Its taste is acrid and bitter. It is unalterable in the air, insoluble in cold, but soluble in boiling water. It is used in medicine under the name of the flowers of Benjamin. Its salts are called *benzoates*.

10. *Succinic Acid*. This is prepared from amber. It takes the form of shining white

crystals, of a slight acid taste. It sublimes in a great heat; is soluble in hot, but dissolves in small quantities in cold water. It is useful as a re-agent, but is of no use in the arts. Its salts are called *succinates*.

11. *Camphoric Acid*. This compound has not hitherto been found in any plant, and is procured only by digesting camphor for a considerable time in a large excess of nitric acid. It is sparingly soluble in water. Its taste is rather bitter, and its odour somewhat similar to saffron. It reddens litmus paper, and combines with alkalies, forming salts called *camphorates*.

12. *Moroxylic Acid*. A compound discovered by Klaproth, in combination with lime or the bark of the *morus alba* or white mulberry.

13. *Hydrocyanic or Prussic Acid*. This acid was discovered by Scheele in 1782, and Bartholet afterwards ascertained that it contains carbon, nitrogen and hydrogen; but Gay-Lussac first procured it in a pure state, and by the discovery of cyanogen, was enabled to determine its real nature. In a pure state, prussic acid is a limpid colourless fluid, of a strong odour, similar to that of peach blossoms. It excites at first a sensation of coolness on the tongue, which is soon followed by heat; but when diluted, it has the flavour of bitter almonds. It unites with water and alcohol in every proportion. The distilled water from the leaves of the *prunus lauro cerassus*, owes its poisonous quality to the prussic acid it contains.

14. *Sorbic Acid*. This is found to be the malic acid.

15. *Rheumic Acid*. This name was applied to the acid principle contained in the stem of the

CHAPTER XII.

MINERAL ACIDS.

Sulphuric Acid. A combination of sulphur and oxygen—commonly called oil of vitriol. It is procured by burning sulphur in contact with oxygen, and becomes acidified.

Obs.—Sulphuric acid, at the instant of its formation, is in a gaseous state; the manufacturers, therefore, find it necessary to condense this gas by means of water. Hence the sulphuric acid of commerce is always in a fluid state. It is a good test for barytes and lead. It is a very ponderous, corrosive acid, destitute of colour and smell, and has a very strong acid taste. It has a great attraction for water, and combines so intimately with this fluid that the compound gives out a portion of caloric; and when combined with the alkalies, the earths, and metallic oxides, it forms with them those salts called *sulphates*.

Sulphurous Acid. This, like the sulphuric acid, is a combination of sulphur and oxygen, but with less oxygen and more sulphur than the latter. It is capable of uniting with various bases, and forms the salts called *sulphates*.

Sulphurous acid Gas may be procured by the following process:—Put into a glass retort two parts of sulphuric acid and one of mercury, and apply the heat of a lamp; the mixture effervesces, and a gas issues from the beak of the retort, which may be received in glass jars filled with mercury and standing in a mercurial trough. In this process the mercury in the retort combines with part of the oxygen of the sulphuric acid;

and the sulphuric acid, having lost a certain portion of its oxygen, is converted into *sulphurous acid*.

Obs.—Any combustible substance will decompose sulphuric acid, by combining with a portion of its oxygen, and sulphurous acid gas will be evolved. It is used in bleaching silk: and possesses very slight acid properties. Instead of changing vegetable blues to a red, as acids generally do, it invariably renders them white. Thus, if a red rose be held in the fumes of a brimstone match, the colour will soon begin to change, and ultimately the flower will become white. By the same process, fruit stains or iron moulds may be removed from linen or cotton cloths, if the spots be previously moistened with water.

Muriatic Acid. This is a peculiar acid, obtained from sea salt; whose radical or base until lately was entirely unknown. It is distilled from sea salt by means of sulphuric acid, and collected in appropriate receivers, where it is condensed in water for which it has a powerful affinity.

Properties. This acid in the gaseous state is invisible like air; and has a pungent suffocating smell. With water it forms the liquid muriatic acid, which procures the smell of the gas, and gives out white fumes when exposed to the atmosphere. It is much employed in the arts and chemical laboratories. With various bases, it forms the salts called *muriates*.

Obs.—Muriatic acid may be obtained for chemical experiments, by pouring one part of sulphuric acid upon two parts of dry muriate of soda in a tubulated retort, and collecting the gas, as it becomes disengaged, over mercury in a pneumatic apparatus. It may also be collected by heating the muriatic acid of commerce in a glass retort.

Esp.—Muriatic acid is the best test for silver. If a single drop be poured into any solution containing this metal, a copi-

ous precipitate will immediately follow, owing to the affinity of this acid for silver, and the insolubility of muriate of silver.

Oxymuriatic Acid. Chlorine. The oxymuriatic acid, according to Sir H. Davy, is a simple substance. It is known in the gaseous state, and in combination with water: in the latter form it is commonly used in the arts. The discovery of chlorine was made in 1770 by Scheele, while investigating the nature of manganese, and he described it under the name of dephlogisticated marine acid. The French chemists called it oxygenized muriatic acid, a term which was afterwards contracted to *oxymuriatic acid*, from an opinion proposed by Berthollet, that it is a compound of muriatic acid and oxygen. Chlorine gas is obtained by the action of muriatic acid on manganese.

Properties. Chlorine gas is of a yellowish-green colour, has an astringent taste, and a disagreeable odour. It is one of the most suffocating of the gases, exciting spasm and great irritation of the glottis, even when considerably diluted with air. Cold recently-boiled water, at the common pressure, absorbs twice its volume of chlorine, and yields it again when heated. This solution, which is made by passing a current of chlorine gas through cold water, has the colour, taste, and most of the other properties of the gas itself. It supports combustion. If a lighted taper be plunged into chlorine gas, it burns with a small red flame, and emits a large quantity of smoke. Phosphorus takes fire in it spontaneously, and burns with a pale white light. Several of the metals, such as tin, copper, arsenic, antimony and zinc, when introduced into chlorine in the state of powder, or in fine leaves, are sudden-

ly inflamed. In all these cases the combustible substances unite with chlorine.* It possesses no acid properties—it has not a sour taste—does not redden the blue colour of plants, and shows little disposition to unite with alkalies. One of the most important properties of chlorine is its bleaching power: all animal and vegetable colours are speedily removed by it; and when the colour is once discharged, it can never be restored.* Chlorine is useful, likewise, for fumigation. The experience of Guyton Morveau is sufficient evidence of its power in destroying the volatile principles given off by putrefying animal matter: and probably it may act in a similar way on contagious effluvia. The compounds of chlorine which are not acid are termed *chlorides* or *chlorurets*. It is the only acid that will dissolve gold and platina. With various bases it forms salts, called hyper-oxy muriates.

Nitric Acid. This is one of the constituent parts of nitre or saltpetre. It is a composition of oxygen and nitrogen, in the proportion of about twenty-six parts by weight of the latter to about seventy-four of the former. It is obtained by distilling two parts of nitre and one of sulphuric acid in a glass retort, and collecting the fluid in proper receivers. This acid, which at

* Its strong affinity for the metals is sufficient to prove that it is not an acid; for chemists are not acquainted with any instance of direct combination between an acid and a metal.

† Muriatic acid removes the stains of common ink, but it does not effect printers' ink. It is, therefore, recommended for cleaning old books and prints. Half an ounce of red lead being added to three ounces of common muriatic acid, will render it fit for this use. Where writings have been effaced for fraudulent purposes with this acid, sulphuret of ammonia and prussiate of potass will revive the writing, and discover the artifice. Very old writing may be revived in this way. If indigo and oxide manganese be added to common ink, it will prevent its being effaced by oxymuriatic acid.

first contains nitrous gas, is in a great measure deprived of it and rendered transparent and colourless by the application of heat in a subsequent process.

Properties.—Nitric acid is clear and colourless like water; its smell is pungent, its taste exceedingly acid, and its action on animal substances very corrosive. It has the property of permanently staining the skin yellow; has a great affinity for water; is capable of oxydizing most of the metals; and, with various bases, forms the salts called *nitrates*.

Nitric acid is drawn of different strengths, according to the purposes for which it is designed. It is used in dyeing, in refining gold, in medicine, and in a great variety of manufactories. A mixture of nitric and muriatic acids, in the proportion of one measure of the former to two of the latter, has long been known under the name of *aqua-regia* (nitro-muriatic acid), as a solvent for gold and platinum. When these acids are mixed together, the solution instantly becomes yellow; and on heating the mixture, pure chlorine is evolved, and the colour of the solution deepens. On continuing the heat, chlorine and nitrous acid vapours are disengaged; at length the evolution of chlorine ceases, and the residue liquid is found to be a solution of muriatic and nitrous acid, which is incapable of dissolving gold.

Nitrous Acid, improperly so called, is in fact nitric acid impregnated with variable proportions of nitrous gas. It constitutes the acid of commerce. In its properties it is very similar to nitric acid; but its colour varies according to the proportions of nitrous gas which it has absorbed, and the water it contains. It is generally

used for purposes of manufacture and experiment.

Obs.—The changes which take place on the addition of water to strong nitrous acid, exhibit very curious phenomena. Different portions change its colour to a blue, a green, a yellow, &c., while the vapours which rise from it preserve their original flame-coloured red. It is to Dr. Priestly we are indebted for the discovery that nitrous gas is converted into nitrous acid by its union with oxygen and water.

Carbonic Acid.—A combination of carbon and oxygen. It was formerly called fixed air, on account of its being so intimately combined in chalk, limestone, magnesia, &c. It was discovered by Dr. Black in 1757, and described by him in his inaugural dissertation *de Magnesia alba*, under the name of fixed air. It is most conveniently prepared for purposes of experiment by the action of muriatic acid, diluted with two or three times its weight of water, on fragments of marble. The muriatic acid unites with the lime, and the carbonic acid escapes with effervescence. Thus prepared it is a colourless inodorous fluid, which possesses all the physical characters of the gases in an eminent degree, and requires a pressure of thirty-six atmospheres to condense it into a liquid.

Properties.—It extinguishes burning substances of all kinds. Bodies when immersed in it, do not cease to burn from a want of oxygen only; it exerts a positive influence in checking combustion, as appears from the fact that a candle cannot burn in a gaseous mixture composed of four measures of atmospheric air, and one of carbonic acid. It is not better qualified to support the respiration of animals; its presence, even in moderate proportion, being soon

fatal. An animal cannot live in air which contains sufficient carbonic acid for extinguishing a candle, and hence the practical rule of letting down a burning taper into old wells or pits before any one ventures to descend.

Carbonic acid is quit incombustible, and cannot be made to unite with an additional portion of oxygen. It is a compound, therefore, in which carbon is in its highest degree of oxydation. Lime water becomes turbid when brought into contact with it. The lime unites with the gas, forming carbonate of lime, which, from its insolubility in water, at first renders the solution milky, and afterwards forms a white flaky precipitate. Hence lime water is not only a valuable test of the presence of carbonic acid, but is frequently used to withdraw it altogether from any gaseous mixture that contains it.

Carbonic acid is absorbed by water. Recently boiled water dissolves its own volume of carbonic acid at the common temperature and pressure; but it will take up more if the temperature be increased.

Water and other liquids which have been charged with carbonic acid under great pressure, lose the greater part of the gas when the pressure is removed. The effervescence which takes place on opening a bottle of ginger beer, cider, or brisk champaign, is owing to the escape of carbonic acid gas; and the agreeable pungency of beer, porter, and ale, is, in a great measure, owing to the presence of carbonic acid, by the loss of which, on exposure to the air, they become stale. Boiled water, on the contrary, has an insipid taste from the absence of carbonic acid. It enters into combination with the al-

kalies, earths, and metallic oxides, and forms with them the salts called *carbonates*.

Obs.—Carbonic acid is found in abundance in many natural waters; for instance those of Pyrmont, Spa, and Seltzen. These waters are so pleasant and salutary, that various imitations of them, made in this country, are sold under the names of single and double soda water.

Phosphoric Acid.—This acid formerly was only procured by burning phosphorus in oxygen gas; but since it became known, by Scheele in 1772, that phosphoric acid is a component part of animal bones, it is now obtained at a much cheaper rate. It is very soluble in water; the solution is colourless; it has a strong acid taste; by evaporation the solution becomes very dense, and of an oily consistence. It may be evaporated to dryness, and even submitted to a white heat, without suffering any change, or being volatilized. By its union with earthy, alkaline, and metallic bases, that variety of salts which is called *phosphates*; and occurs in nature combined with lime, oxide of lead, and other bases.

Phosphorous Acid contains a smaller proportion of oxygen than the phosphoric acid. It is procured by the slow combustion of phosphorus; for when phosphorus is heated it burns *rapidly*, and the product is phosphoric acid. It is a dense, viscid liquid, with an acid taste, and when heated emits the smell of garlic. Like the phosphoric acid, it may be decomposed by charcoal; but cannot be obtained in a concrete state. It has not hitherto been applied to any use. The salts formed with it are called *phosphites*.

Q. What is fluoric acid?

A. It is an acid of a very peculiar nature, found in the fluor spar, a mineral production

composed of fluoric acid and lime. In a state of gas, it is invisible like air; water absorbs it rapidly, and forms liquid fluoric acid. It has an acid taste, and the peculiar property of corroding silex; and, though it has been decomposed, the nature of its radical is not yet known. It is only used for etching upon glass, for which purpose it was first employed in the seventeenth century.

Q. What is boracic acid?

A. The boracic is a peculiar acid separated from a substance called borax.

Q. What are the properties of boracic acid?

A. It is in the form of thin salts, slightly acid, and unalterable in the air. It forms the variety of salts called *borates* when combined with the alkalies, some earths, and some of the metallic oxides. One of the peculiar properties of this acid is, that it imparts a green colour to burning bodies.

Obs.—The taste of this acid is bitterish with a degree of acidity. It is very soluble in hot water, and but sparingly so in cold. It is very useful in the analysis of minerals, as it brings almost all stones into solution.

Q. What is arsenic acid?

A. Arsenic acid is a compound of arsenic and oxygen. It is a heavy, thick, incrustable mass, very soluble in hot water, of an acid taste, and poisonous. With different bases it forms the salts called *arseniates*. It is made by giving an extra dose of oxygen to the common white oxide of arsenic.

Q. What is tungstic acid?

A. It is a tasteless yellow powder, composed of oxygen and tungsten. It is insoluble in water, but forms the salts called *tungstates*, by its union

with alkalies, earths, or metals. It dissolves several metals.

Q. What is molybdic acid?

A. Molybdic acid is a pale yellow powder, composed of molybdenum and oxygen. It requires a large quantity of water to dissolve it. When combined with salifiable bases, the compounds are called *molybdates*.

Obs.—There is another combination of molybdenum and oxygen, called the *molybdous* acid, which is in the state of a fine blue powder. For the process of making it, see Sir H. Davy's Elements of Chem. Philos., part i. p. 400.

Q. What is chromic acid?

A. An orange-coloured powder, composed of chromium and oxygen. It has an acrid metallic taste, and is soluble in water and crystallizable. When mixed with different saline solutions it assumes a variety of beautiful colours; it also forms with the earths and alkalies various salts called *chromates*.

Obs.—The chromic acid was discovered by Vauquelin. He procured it from the red lead ore of Siberia. For an account of the different colours this acid assumes, see Dr. Thompson, vol. ii. p. 105.

CHAPTER XIII.

SALTS.

Q. WHAT do chemists understand by the term Salt?

A. By the term salt, is chemically understood

a definite compound of an acid, and of an alkaline or salifiable base, both of which are in every case composed of at least two simple substances.

Ex.—Sulphate of potass, for instance, is a salt, the acid of which consists of oxygen and sulphur, and the base of oxygen and potassium.

Q. What are the characteristic features of salts?

A. Nearly all salts are solid, and most of them assume crystalline forms when their solutions are spontaneously evaporated. They are variable in colour, and differ remarkably in their affinity for water. All soluble salts are more or less rapid, while those that are insoluble in water are insipid. Few salts are possessed of odour: the only one remarkable for this property is the carbonate of ammonia. They also differ in the degree of solubility in water; and those which are soluble in water crystallize more or less regularly when their solutions are evaporated, &c.

Obs.—The same quantity of water may hold different salts in solution, provided they do not mutually decompose each other. Indeed the solvent power of water with respect to one salt, is sometimes increased by the presence of another, owing to combination taking place between the two salts. Most salts produce cold during the act of dissolving in water, especially when they are dissolved rapidly and in large quantity. The greatest reduction of temperature is occasioned by those salts which contain water of crystallization. All salts are decomposed by voltaic electricity, provided they are either moistened or in solution, and their composition is subject to the laws of chemical union.

The combination of salts with one another gives rise to compounds which were formerly called *triple salts*; but as the term *double salt*,

proposed by Berzelius, gives a more correct idea of their nature and constitution, we shall here always employ it in preference. These salts may be composed either of one acid and two bases, or two acids and one base; and most probably of two different acids and two different bases. Nearly all the double salts hitherto examined, consist of the same acid and two different bases. (For the nomenclature of salts, see *Acids*.)

**SULPHATES.—SULPHITES.—HYPOSULPHATES.—
HYPOSULPHITES.**

SULPHATES.—Several of the sulphates exist in nature; but the only ones which are abundant, are the sulphates of lime and baryta: all of them may be formed by the action of sulphuric acid on the metals themselves, on the metallic oxides or their carbonates, or by way of double decomposition. The solubility of the sulphates is very variable. There are six only which may be regarded as insoluble; namely, the sulphates of baryta, tin, antimony, bismuth, lead, and mercury. The sparingly soluble sulphates are those of strontia, lime, zirconia, yttria, cerium, and silver. All the others are soluble in water.

All the sulphates, those of potassa, soda, lithia, baryta, strontia, and lime excepted, are decomposed in a white heat; one part of the sulphuric acid of the decomposed sulphate escapes unchanged, and the other portion is resolved into sulphurous acid and oxygen. Those which are easily decomposed by heat, such as the sulphate of iron, yield the largest quantity of undecomposed sulphuric acid.

When a sulphate, mixed with carbonaceous

matter, is ignited, the oxygen both of the acid and of the oxide unites with carbon, carbonic acid is disengaged, and a metallic sulphuret remains. A similar change is produced by hydrogen gas at a red heat, with formation of water, and frequently of some sulphuretted hydrogen.

Obs.—The salts of sulphuric acid in solution may be detected by muriate of baryta. A white precipitate, the sulphate of baryta, invariably subsides, which is insoluble in all the acids and alkalies, a character by which the presence of sulphuric acid, whether free or combined, may always be recognised. An insoluble sulphate, such as the sulphate of baryta or strontia, may be detected, by mixing it, in fine powder, with three times its weight of the carbonate of potassa or soda, and exposing the mixture in a platina crucible for half an hour to a red heat. Double decomposition ensues; and on digesting the residuum in water, filtering the solution, neutralizing the free alkali by pure muriatic, nitric or acetic acid, and adding the muriate of baryta, the insoluble sulphate of the base is precipitated.

Sulphate of Potass.—This salt is easily artificially prepared by neutralizing the carbonate of potass with sulphuric acid; and it is procured abundantly as a product of the operation for preparing nitric acid.

Taste.—Saline and bitter.

Form.—It crystallizes in six-sided prisms, bounded by pyramids with six sides. The crystals contain no water of crystallization, and suffer no change by exposure to the air.

Properties.—They decrepitate when heated, and enter into fusion at a red heat; and they require sixteen times their weight of water at 60° F., and five of boiling water for solution.

Composition.—The sulphate of potass is com-

posed of forty parts or one atom of sulphuric acid to forty-eight parts or one atom of potass.

Obs.—The bisulphate of potass, which contains twice as much acid as the sulphate, is easily formed by digesting eighty-eight parts, or one atom of the neutral sulphate, with water containing about thirty parts of concentrated sulphuric acid, and evaporating the solution. It has a strong sour taste, and reddens litmus paper. It is much more soluble than the neutral sulphate, requiring for solution only twice its weight of water at 60°, and less than an equal weight at 212° F. It is resolved by heat into sulphuric acid and the neutral sulphate.

Sulphate of Soda, commonly called *Glauber's Salt*, is occasionally met with on the surface of the earth, and is frequently contained in mineral springs. It may be made by the direct action of sulphuric acid on the carbonate of soda, and it is procured in large quantity as a residue in the processes for forming muriatic acid and chlorine.

Taste.—Cooling, saline, and bitter.

Form.—Four and six-sided prismatic crystals, which effloresce rapidly when exposed to the air; and readily undergo the watery fusion when heated. They dissolve in three times their weight of water at 60° F.

Composition.—According to Berzelius they are composed of seventy-two parts or one atom of the neutral sulphate, and ninety parts or ten atoms of water.

Obs.—The bisulphate of soda may be formed in the same manner as the analogous salt of potass.

Sulphate of Ammonia, prepared by neutralizing the carbonate of ammonia with dilute sulphuric acid. It crystallizes in long flattened

six-sided prisms. It dissolves in two parts of water at 60°, and in an equal weight of boiling water. It is sublimed by heat, but at the same time is partially decomposed. The crystals are composed of 40 parts or one atom of acid, and 17 parts or one atom of ammonia combined; according to Dr. Thompson, with one atom, and according to Berzelius, with two atoms of water.

Sulphate of Baryta.—The native sulphate of Baryta, commonly called *heavy spar*, occurs abundantly, chiefly massy, but sometimes in anhydrous crystals, the form of which is variable, being sometimes prismatic and sometimes tubular. It is easily formed artificially by the way of double decomposition. It leaves an intense heat without fusing or undergoing any other change, and is one of the most insoluble substances chemists are acquainted with. According to Dr. Thompson it is composed of 78 parts, or one atom of baryta, and 40 parts or one atom of sulphuric acid. It is sparingly dissolved by hot and concentrated sulphuric acid, but is precipitated by the addition of water. Its density is 4.4.

Sulphate of Strontia.—This is the celestine of mineralogists, and is less abundant than heavy spar. It occurs in prismatic crystals of peculiar beauty in Sicily. Its density is 3.858. Obtained by the way of double decomposition, it is a white heavy powder, very similar to the sulphate of baryta. It requires 3840 times its weight in water for solution. It contains, according to Dr. Thompson, 32 parts or one atom of strontia, and one atom of sulphuric acid.

Sulphate of Lime.—This is easily formed by mixing a solution of the muriate of lime with

any soluble sulphate. It occurs abundantly as a natural production. The mineral called *anhydrite* is the anhydrous sulphate of lime; and all the varieties of *gypsum* are composed of the same salt, united with water. The pure crystallized specimens of gypsum are sometimes called *selenite*; and the white compact variety is employed in statuary under the name of alabaster.

Obs.—The sulphate of lime has hardly any taste. It is considerably more soluble than the sulphates of baryta or strontia, requiring for solution about 300 parts of cold, and 450 of boiling water. To this circumstance, and to its existing so abundantly in the earth, it is frequently contained in spring water, to which it communicates the property called hardness. When freshly precipitated, it may be dissolved completely by dilute nitric acid.

Sulphate of Magnesia.—This is generally known by the name of *Epsom salt*, and is frequently contained in mineral springs. It may be made directly by neutralizing dilute sulphuric acid with carbonate of magnesia; but it is procured for the purposes of commerce by the action of dilute sulphuric acid or magnesia limestone, the native carbonate of lime and magnesia.

Taste.—Saline, bitter and nauseous.

Form, &c.—It crystallizes readily in small quadrangular prisms, which effloresce slightly in a dry air. According to Gay-Lussac, the crystals are composed of 60 parts or one atom of the dry sulphate, and 63 parts or seven atoms of water. They are soluble in an equal weight of water at 60° F. and in three-fourths their weight in boiling water. They undergo the watery fusion when heated; and the anhydrous

salt is deprived of a portion of its acid at a white heat.

Sulphate of Alumina.—The pure sulphate of alumina is a compound of little interest; but with the sulphate of potass it forms an interesting double salt, the well-known alum of commerce. With the sulphate of ammonia and the sulphate of soda, the sulphate of alumina forms double salts very analogous to common alum. The solution of the sulphate of alumina reddens litmus paper; but it is doubtful whether this be owing to an excess of acid or to the weak affinity existing between alumina and sulphuric acid. It crystallizes readily in octahedrons, or in segments of an octahedron, and the crystals contain almost 30 per cent. of water of crystallization.

Sulphate of Iron.—The sulphate of the protoxide of iron, commonly called *green vitriol*, is formed by the action of dilute sulphuric acid or metallic iron, or by exposing the protosulphuret of iron in fragments to the combined agency of air and moisture. This salt has a strong styptic earthy taste. It reddens the vegetable blue colours, though neutral in its composition; is soluble in two parts of cold water, and in three-fourths of its weight of boiling water. It occurs in transparent pale green-coloured rhombic crystals, which consist, according to Berzelius, of 76 parts or seven atoms of water. In the anhydrous state it is of a dirty white colour. This is the salt employed in the fuming sulphuric acid.

Sulphate of Zinc, frequently called white vitriol, is the residue of the process for forming hydrogen gas by the action of dilute sulphuric acid on metallic zinc, but is made, for the purposes of commerce, by roasting the native sul-

phuret of zinc in a reverberatory furnace. It crystallizes by spontaneous evaporation in transparent four-sided prisms, which dissolve in two parts and a half of cold, and are still more soluble in boiling water. It has a strong styptic taste, though in composition it is strictly a neutral salt, consisting of one atom of each of its elements: it reddens vegetable blue colours.

Sulphates of Copper.—The sulphate of the protoxide of copper has not yet been obtained in a separate state. The sulphate of the peroxide of copper, the *blue vitriol* employed by surgeons as an escharotic and astringent, may be prepared for chemical purposes by dissolving the peroxide of copper in dilute sulphuric acid: but it is procured for sale by roasting the native sulphuret so as to bring both its elements to a maximum of oxidation. This salt forms regular crystals of a blue colour, reddens litmus paper, and is soluble in about four of cold and two parts of boiling water. According to the researches of Proust, Thompson, and Berzelius, it is composed of 80 parts or one atom of the peroxide of copper, 80 parts or two atoms of acid, and 90 parts or ten atoms of water. It is therefore strictly a bisulphate.

Obs.—The sulphate of copper and ammonia is generated by dropping pure ammonia into a solution of the bisulphate, until the sub-salt at first thrown down is nearly all dissolved. It forms a dark blue solution, from which, when concentrated, crystals are deposited by the addition of alcohol. It may be formed also by rubbing briskly in a mortar two parts of the crystallized bisulphate of copper, with three parts of carbonate of ammonia, until the mixture acquires an uniform deep and blue colour. Carbonic acid gas is disengaged with effervescence during the operation, and the mass becomes moist, owing to the water of the blue vitriol being set free. This compound,

which is the *ammoniaret of copper* of the pharmacopœia, contains sulphuric acid, peroxide of copper, and ammonia; but its precise nature has not been determined in a satisfactory manner. It parts gradually with ammonia by exposure to the air.

Sulphates of Mercury.—If in three parts of strong sulphuric acid, two parts of mercury are gently heated so as to cause a slow effervescence, a sulphate of the protoxide of mercury is generated. But if a strong heat is employed in such a manner as to excite brisk effervescence, and the mixture is brought to dryness, a pure sulphate of the peroxide results. The former is composed of one atom of sulphuric acid and one atom of the protoxide; and the latter of two atoms of acid and one atom of the peroxide.
Thompson.

Obs.—When this bisulphate, which is the salt employed in making corrosive sublimate, is thrown into hot water, decomposition ensues, and a yellow sub-salt, formerly called *turpeth mineral*, subsides. This salt is composed of one atom of the acid and one atom of the peroxide. The hot water retains some of the sulphate in solution, together with free sulphuric acid.

SULPHITES, or the salts of sulphurous acid, have not hitherto been minutely examined.

The sulphites of potass, soda, and ammonia, which are made by neutralizing these alkalies with sulphurous acid, are soluble in water; but most of the other sulphites, so far as is known, are of sparing solubility. The sulphites of barytes, strontia and lime, are very insoluble, and consequently the soluble salts of these earths decompose the alkaline sulphites. The stronger acids, such as the sulphuric, muriatic, phosphoric, and arsenic acids, decompose all the sulphites with

effervescence, owing to the escape of sulphurous acid, which may easily be recognised by its odour. The nitric acid, by yielding oxygen, converts the sulphites into sulphates.

**NITRATES.—NITRITES.—CHLORATES.—
IODATES.**

NITRATES.—Q. How are the nitrates prepared?

A. By the action of nitric acid on metals, on the salifiable bases themselves, or on carbonates.

Obs.—As nitric acid forms soluble salts with all alkaline bases, the acid of the nitrates cannot be precipitated by any reagent.

Q. How are the nitrates distinguished from other salts?

A. The nitrates are readily distinguished from other salts by the three following characters:—

1. By deflagrating with red hot charcoal.
2. By their power of dissolving gold-leaf on the addition of muriatic acid.
3. By the evolution of dense, white, acid vapours, which, by their odour, are easily recognised to be nitric odour, when mixed with strong sulphuric acid.

Obs.—All the nitrates are decomposed without exception by a high temperature. Some of the salts, of which common nitre is an example, are at first converted with disengagement of oxygen gas into nitrites; and then by continuing the heat, the nitrous acid is resolved almost entirely into oxygen and nitrogen gas, and pure potass remains. In others, such as the nitrates of barytes, strontian, the acid is apparently changed at once into oxygen and nitrogen, without forming a nitrite. The nitrate of lead yields oxygen and nitrous acid; and the nitrate of palladium, which is decomposed without the application of a strong heat, emits nearly pure nitric acid. And as the

nitrates are easily decomposed by heat alone, they must necessarily suffer decomposition by the united agency of heat and combustible matter.

*. * The process of oxydizing substances by means of nitre, is called *deflagration*, and is generally performed by mixing the inflammable body with an equal weight of the nitrate, and projecting the mixture in small portions at a time into a red hot crucible.

All the neutral nitrates of the fixed alkalies and alkaline earths, together with most of the neutral nitrates of the common metals, are composed of one atom of nitric acid, and one atom of a protoxide. Consequently, the oxygen of the oxide and acid in all such salts must be in the ratio of 1 to 5.

The only nitrates found native, are those of potassa, soda, lime, and magnesia. The others are prepared by the action of nitric acid in their respective bases: *e. g.*

Nitrate of Ammonia
_____ Baryta
_____ Strontia
_____ Copper
_____ Lead*
_____ Mercury
_____ Silver

NITRITES.—Concerning the compounds of nitrous acids with alkaline bases, called nitrites, little is known with certainty. Two nitrites of lead have been described in the *Annales de Chimie*, vol. lxxxiii., by M. Chevreul and M. Berzelius. It is possible, however, that these compounds are hyponitrates.

* Berzelius formed a dinitrate of lead, composed of one atom of acid to two atoms of the protoxide, by adding to a solution of the neutral nitrate a quantity of pure ammonia to separate all the acid.

CHLORATES.—The salts of chloric acid. These are very analogous to the nitrates.

As the chlorates of the alkalies, alkaline earths, and most of the common metals, are composed of one atom of chloric acid, and one atom of a protoxide, it follows that the oxygen of the latter is to that of the former in the ratio of 1 to 5. The chlorates are decomposed by a red heat, nearly all of them being converted into metallic chlorates, with evolution of pure oxygen gas. They deflagrate with inflammable substances with greater violence than the nitrates, yielding oxygen with such facility, that an explosion is produced by slight causes.

Ex.—A mixture of sulphur with three times its weight of chlorate of potass, explodes when struck between two hard substances.

2. With charcoal, and the sulphurets of antimony and arsenic, the salt forms similar explosive mixtures, and with phosphorus it detonates violently by percussion.

Obs.—The mixture employed in the percussion locks for guns, consists of sulphur and the chlorate of potass. All the chlorates hitherto examined are soluble in water, with the exception of the proto-chlorate of mercury, which is of sparing solubility. The chlorates are distinguished by the action of strong muriatic and sulphuric acids, the former of which occasions the derangement of the chlorine and the protoxide of chlorine, and the latter of the peroxide of chlorine. None of these salts are found native. The only ones that require a particular description are the chlorates of potassa and baryta.

Chlorate of Potassa, formerly called oxymuriate, or hyper-oxymuriate of potassa, is colourless, and crystallizes in four and six-sided scales of a pearly lustre. It is soluble in sixteen times its weight of water at 60° F., and in two

and a half of boiling water. It is quite anhydrous, and at a temperature of 400 or 500° F. undergoes the igneous fusion. It is made by transmitting chlorine gas through a concentrated solution of pure potass, until the alkali is completely neutralized.

Chlorate of Baryta is of interest, as being the compound employed in the formation of chloric acid. The readiest mode of preparing it is that suggested by Mr. Wheeler:—Digest for a few minutes a concentrated solution of the chlorate of potass with a slight excess of silicated fluoric acid, and the acid will become precipitated in the form of an insoluble double fluuate of silica and potassa, while the chloric acid remains in solution. The liquid after filtration by carbonate of baryta, likewise throws down the excess of fluoric acid silica. The silicated fluoric acid employed in the process is made by conducting fluosilicic acid gas into water.

IODATES.—There is such a close analogy in the composition of chloric and iodic acids, that the general character of the chlorates and iodates must be similar. The latter are easily known by the facility with which acid is decomposed by deoxygenizing agents. Thus the sulphurous, phosphorous, muriatic, and hydriodic acids deprive the iodic acid of its oxygen, and set iodine at liberty. Sulphuretted hydrogen not only decomposes the acid of these salts, but occasions the formation of hydriodic acid by yielding hydrogen to the iodine. Hence, an iodate may be converted into an hydriodate by transmitting a current of sulphuretted hydrogen gas through its solution.

Obs.—None of the iodates have been found native. They are all very sparingly soluble, or actually insoluble in water, excepting the iodates of the alkalies.

Iodates of Potass.—This salt is easily procured by adding iodine to a concentrated hot solution of pure potass, until the alkali is completely neutralized.

Obs.—All the insoluble iodates may be procured from this salt (iodate of potass) by double decomposition. Then the iodate of baryta may be formed by mixing the muriate of baryta with a solution of the iodate of potass.

PHOSPHATES.—PHOSPHITES.—ARSENIATES.— ARSENITES.

PHOSPHATES.—Several phosphates are met with in the native state, such as those of lime, manganese, iron, uranium, copper and lead.

Phosphate of Soda.—Of the alkaline phosphates, that with base of soda is the one generally employed, owing to the facility with which it is obtained in crystals. It is prepared on a large scale in chemical manufactories, by neutralizing the super-phosphate of lime, procured by the action of sulphuric acid on burned bones with carbonate of soda.

Obs.—This salt crystallizes in rhombic prisms, which effloresce on exposure to the air, and require four parts of cold or two of boiling water for solution. It is employed in medicine as a laxative, and in chemistry as a reagent.

Phosphate of Soda and Ammonia.—This salt is prepared by dissolving one atom of muriate of ammonia and five atoms of phosphate of soda in a small quantity of boiling water. It has long been known by the name of *microcosmic salt*, and is much employed as a flux in experiments with the blow-pipe.

Phosphate of Lime.—This is the compound of which many urinary concretions consist. It appears, according to the researches of Berzelius and others, to consist, as it exists in bones, or as obtained by mixing muriate of lime with neutral phosphate of soda in excess, of 28 parts, or one atom of phosphoric acid, and 28 or one atom of lime. The biphosphate of lime may be prepared by adding one atom of phosphoric acid to one atom of the phosphate of lime. It exists in the urine.

Phosphate of Ammonia and Magnesia.—The simple phosphate of magnesia, which is prepared by mixing a solution of the sulphate of magnesia with phosphate of soda, is of little interest; but the double phosphate is of importance as constituting a distinct species of urinary concretion. It is easily procured by adding carbonate of ammonia and afterwards phosphate of soda to a solution of the sulphate of magnesia, when the double phosphate subsides in the form of minute crystalline grains.

Obs.—This salt is insoluble in pure water, but is dissolved by most acids, even by the acetic, and is precipitated unchanged when the solution is neutralized by ammonia. This salt, when strongly heated, fuses and forms a white opaque glass.

Phosphites and Hypophosphites.—These compounds have hitherto been little examined, and are of no material importance, consequently require no particular description.

Obs.—The neutral salts of phosphoric acid with fixed bases sustain a red heat without decomposition, but they are all fusible at a high temperature. The phosphates of the common metals, at least the greater part of them, are converted into phosphurets by the combined agency of heat and charcoal. Most of the phosphates are mostly insoluble or very sparingly so.

ARSENIATES.—All the arseniates are sparingly soluble in water, excepting those of potassa, soda, ammonia, and perhaps of lithia; but they are all dissolved without effervescence by dilute nitric acid, as well as most other acids which do not precipitate the base of the salt, and are thrown down again unchanged by pure ammonia. Most of them bear a red heat; but they are all decomposed by being heated to redness along with charcoal, metallic arsenic being set at liberty. The arseniates of the fixed alkalies and alkaline earths require rather a high temperature for reduction; while the arseniates of the common metals, such as those of lead and copper, are easily reduced in a glass tube by means of a spirit lamp without danger of melting the glass. The arseniate of lead is the most insoluble.

The soluble arseniates are easily recognized by the tests (see *Arsenic*), and the insoluble arseniates, when boiled in a strong solution of the fixed alkaline carbonates, are deprived of their acid, which may then be detected in the usual way. The free alkali, however, should first be exactly neutralized by pure nitric acid.

The arseniates of lime, nickel, cobalt, iron, copper and lead, are natural productions.

. The arsenic acid unites in two proportions with potassa, soda, and ammonia, forming neutral salts and bisalts, all of which, the neutral arseniate of potass excepted, may be obtained in crystals. They are all formed by adding arsenic to the alkaline carbonates.

ARSENITES.—The only soluble compounds of arsenious acid and salifiable bases known to chemists, are the arsenites of potassa, soda,

and ammonia, which may be prepared by boiling a solution of these alkalies in arsenious acid. The other arsenites are insoluble, or, at most, sparingly so in pure water; but they are dissolved by an excess of their own acid, with great facility, by nitric acid, and by most other acids with which their bases do not form insoluble compounds. On exposing the arsenites to heat in close vessels, the arsenious acid is either dissipated in vapour or converted, with disengagement of some metallic arsenic, into arseniates. Heated with charcoal, or black flux, the acid is reduced with facility.

The soluble arsenites, if quite neutral, are characterized by forming a yellow arsenite of silver, when mixed with the nitrate of that base, and a green arsenite of copper, *Scheele's green*, with the sulphate of copper. When acidulated with acetic or muriatic acid, sulphuretted hydrogen causes the formation of orpiment, an effect which it likewise produces in the arseniates. The insoluble arsenites are all decomposed when boiled in a solution of the carbonate of potass or soda.

* * The arsenite of potass is the active principle of Fowler's solution.

CHAPTER XIV.

CHROMATES.—BORATES.—FLUATES.—FLUO-BORATES.

* CHROMATES, or the salts of chromic acid, are mostly either of a yellow or red colour; the latter

tint predominating whenever the acid is in excess. The chromates of the common metals are decomposed by a strong red heat, by which the acid is resolved into the green oxide of chromium and oxygen gas; but the chromates of the fixed alkalies sustain a very high temperature without decomposition. Without exception they are all decomposed by the united agency of heat and combustible matter. The chromates are in general distinguished, sufficiently distinguished, by their colour. They may be known chemically by the following character:—on boiling a chromate in muriatic acid mixed with alcohol, the chromic acid is at first set free, and is then decomposed, a green muriate of the oxide of chromium being generated.

The only native chromate hitherto discovered is the red chromate of lead from Siberia, in the examination of which Vauquelin discovered chromium.

Chromates of Potass, from which all the compounds of chromium are directly or indirectly prepared, is made by heating to redness the native oxide of chromium and iron, commonly called *chromate of iron*, with an equal weight of the nitrate of potass, when the chromic acid is generated, and unites with the alkali of the nitre.

Obs.—The bichromate of potass, which is made in large quantity in Glasgow for dyeing, is prepared by acidulating the neutral chromate with sulphuric acid, and allowing the solution to crystallize by spontaneous evaporation. The insoluble salts of chromic acid, such as the chromates of baryta, lead, protoxide of mercury, and silver, are prepared by mixing the soluble salts of those bases with a solution of the chromate of potassa. The two former are yellow, the third orange, and the fourth

deep red or purple. The yellow chromate is now extensively used as a pigment.

BORATES.—The borates, or salts of boracic acid, are all fusible into glass; and, with most of the metallic oxides, form glass of different colours. Concentrated solutions of some of the borates, especially that of soda, afford by the strong acids scaly crystals of boracic acid. The principal boracic salts are the borates of lime, of magnesia, and of potass.

Obs.—The chief use of borax is as a flux, and for the preparation of boracic acid. The bi-borate of magnesia is a rare natural production, known by the name of *boracite*.

FLUATES.—The principal fluoric salts are the fluates of lime, soda, ammonia, alumine, and silex. They are all decomposed by sulphuric acid, yielding a vapour which corrodes glass, which, when condensed in water, forms liquid fluoric acid. They are not decomposable by mere heat, nor altered by combustibles.

Obs.—Five fluates have hitherto been found native; namely, the fluate of lime, or *fluor spar*, the fluosilicate of alumina or *topaz*, the fluate of cerium, the double fluate of cerium and yttria, and the double fluate of soda and alumina or *cryolite*. The four latter are very rare minerals, but the former is abundant.

FLUOBORATES.—The compounds of this acid with salifiable bases are yet almost entirely unknown,

CHAPTER XV.

CARBONATES.*

Q. How are the carbonates distinguished from other salts?

A. The carbonates are distinguished from other salts by being decomposed with effervescence, in consequence of the escape of carbonic acid gas, by nearly all the acids.

Obs.—With the exception of the carbonates of potassa, soda, and lithia, all the carbonates may be deprived of their acid by heat. The carbonates of baryta and strontia, especially the former, require an intense white heat to decompose them; those of lime and magnesia are reduced to the caustic state by a full red heat, and the other carbonates part with their carbonic acid when heated to dull redness. All the carbonates, excepting those of potassa, soda, and ammonia, are sparingly soluble in pure water; but all of them are more or less soluble in an excess of carbonic acid, owing doubtless to the formation of supersalts.

Several of the carbonates occur in a native state, among which may be enumerated the carbonates of soda, baryta, strontia, lime, magnesia, manganese, protoxide of iron, copper, lead, and the double carbonate of lime and magnesia.

* The nomenclature of the salts is peculiarly exceptionable as applied to the carbonates. The two well known carbonates of potass, for instance, are distinguished by the prepositions *sub* and *super*, as if one had an alkaline and the other an acid re-action; whereas, in fact, according to their action on test paper, they are both sub-salts. We shall, therefore, on the authority of a late writer, apply the generic name of carbonate to those salts which contain one atom of carbonic acid and one atom of the base—compounds which may be regarded as neutral in composition, however they may act on the colouring matter of plants.

CARBONATE OF POTASSA is procured in an impure state by burning land plants, lixiviating their ashes, and evaporating the solution to dryness, a process performed on a large scale in Russia and America. Thus obtained, it is known in commerce by the name of *potash* and *pearlash*, and is employed in many of the arts, especially in making soap and glass. In this condition it always contains other salts, as sulphate and muriate of potass, consequently for chemical purposes, it should be prepared from cream of tartar, the bi-tartrate of potass.

Obs.—Pure carbonate of potass has a strongly alkaline taste, and is slightly caustic; and communicates a green to the blue colour of the violet.

The Bi-carbonate of Potass is made by transmitting a current of carbonic acid gas through a solution of the carbonate of potass. By slow evaporation, the bi-carbonate is deposited from the liquid in regular prismatic crystals. Though milder than the carbonate, it is both alkaline to the taste and to test papers.

CARBONATE OF SODA.—The carbonate of soda of commerce is obtained by lixiviating the ashes of sea-weeds. The best variety is known by the name of *barilla*, and is derived chiefly from the *salsola soda* and *salicornia herbacea*. A very inferior kind, known by the name of *kelp*, is prepared from sea-weeds, on the northern shores of Scotland. The purest *barilla*, however, though well adapted for making soap and glass, and for other purposes in the arts, always contains the sulphates and muriates of potass and soda; consequently is of little service to the chemists. A purer carbonate

is prepared by heating a mixture of sulphate of soda, saw-dust and lime, in a reverberatory furnace; after which it is obtained by lixiviation and crystallization. It is difficult to obtain this salt free from sulphuric acid.

Obs.—The carbonate of soda crystallizes in octahedrons with a rhombic base; the acute angles of which are generally truncated. The crystals effloresce on exposure to air, and, when heated, dissolve their water of crystallization.

Bi-carbonate of Soda is made by transmitting a current of carbonic acid gas through a solution of the carbonate, and is deposited in crystalline grains by evaporation. Though alkaline, it is much milder than the carbonate, and far less soluble.

Sesqui-carbonate of Soda is a compound that occurs native on the banks of the lakes in the province of Sukena in Africa, whence it is exported under the name of *Trona*.

CARBONATE OF AMMONIA.—The only method of procuring this salt is by mixing dry carbonic acid over mercury, with twice its volume of ammoniacal gas. It is a dry volatile powder, of an ammoniacal odour, and alkaline re-action.

Bi-carbonate of Ammonia is formed by Berthollet, by transmitting a current of carbonic acid gas through a solution of the common carbonate of ammonia of the shops.

Sesqui-carbonate of Ammonia.—The sub-carbonate of ammonia of the shops, is different from both these compounds. It is prepared by heating a mixture of one part of muriate of ammonia with one part and a half of the carbonate of lime, carefully dried.

CARBONATE OF BARYTES.—This occurs abundantly in the lead mines in the north of Eng-

land, where it was discovered by Dr. Withering, whence it received the name of *Witherite*. It may be prepared by double decomposition, by mixing a soluble salt of baryta with any of the alkaline carbonates or bi-carbonates. It is highly poisonous.

CARBONATE OF STRONTIA occurs native at Strontian in Argylshire, and is known by the name of *Strontianite*. It may be prepared in the same way as the carbonate of barytes. It is very insoluble in water, but is dissolved by an excess of carbonic acid.

CARBONATE OF LIME.—This salt occurs abundantly in a natural state under a variety of forms, as common lime-stone, chalk, marble, and Iceland spar, and in regular crystals. It may also be formed by precipitation. It is sparingly soluble in water, but may be dissolved by carbonic acid in excess.

CARBONATE OF MAGNESIA.—This salt is easily prepared by adding carbonate of potass in slight excess to a hot solution of sulphate of magnesia, andedulcorating the precipitated carbonate with warm water.

Obs.—The native carbonate of magnesia, according to the analysis of Dr. Henry and Stromeyer, is similar in composition to the precipitated carbonate.

CARBONATE OF IRON.—Carbonic acid does not form a definite compound with the peroxide of iron, but with the protoxide it constitutes a salt which is an abundant natural production, occurring sometimes massy, and at other times crystallized in rhomboids or hexagonal prisms. This protocarbonate of iron is contained also in most of the chalybeate mineral waters, being held in solution by free carbonic acid; and it

may be formed by mixing an alkaline carbonate with the protosulphate of iron. When prepared by precipitation it attracts oxygen rapidly from the atmosphere, and the protoxide of iron passing into the state of peroxide, parts with carbonic acid. It is owing to this, that the carbonate of iron of the pharmacopœia, is of a red colour, and consists chiefly of the peroxide.

CARBONATE OF COPPER.—The beautiful green mineral, called *malachite*, is a carbonate of the peroxide of copper; and a similar compound may be formed from the persulphate by double decomposition, or by exposing metallic copper to air and moisture. (See *Journal of Science*, vol. iv.)

Obs.—The blue pigment called *verditer*, said to be prepared by decomposing the nitrate of copper by chalk, is an impure carbonate.

CARBONATE OF LEAD.—This salt (the white lead or ceruse of painters) occurs native, but may be obtained by double decomposition. It is prepared for the purposes of commerce by exposing coils of thin sheet lead to the vapours of vinegar, when, by the united action of the oxygen of the atmosphere and the acid fumes, the lead is both oxydated and converted into a carbonate.

CHAPTER XVI.

SALTS OF THE HYDRACIDS.

By *salts of hydracids* are meant those saline compounds, the acid of which contains hy-

drogen as one of its elements. These salts, owing to their peculiar constitution, have certain common properties. They are all exposed to the action of divellent and three quiescent affinities.

Ex.—In the muriate of soda the forces which tend to prevent or change are the attraction of sodium for oxygen, of chlorine for hydrogen, and of muriatic acid for soda; while the opposite affinities are the attraction of chlorine for sodium, and of hydrogen for oxygen. The latter always preponderate when heat is employed, because the volatility of water favours the production of that fluid; and in many instances the affinities appear so nicely balanced, that the cohesion of one of the compounds is sufficient to influence the result, as exemplified by the muriate of soda, which, in the act of crystallizing, is converted into the chloride of sodium.*

MURIATES OR HYDROCHLORATES.—Most of the salts of muriatic acid are soluble in water, and some of them exist only in a state of solution.

The muriates are distinguished from other salts by forming the white insoluble chloride of silver when mixed with the nitrate of that base, and by being decomposed with disengagement of muriatic acid. The decomposition of the muriates, owing to the volatile nature of their acid, is effected by the phosphoric and arsenic acids at the temperature of ebullition.

MURIATE OF POTASS AND SODA.—These salts only exist in a state of solution, and are frequently contained in mineral springs. The

* Most of the salts composed of a hydracid and a metallic oxide are so constituted, that the oxygen of the oxide contains a quantity of oxygen precisely for forming water with the hydrogen of the acid. This is true, without exception, of all the neutral compounds containing a protoxide, and it likewise holds good in many other cases. *Turner's Elem. of Chemistry*, p. 499.

muriate of soda, or common table salt, is the chief constituent of sea-water.

MURIATE OF AMMONIA.—The sal ammoniac of commerce, formerly imported from Egypt, where it is procured by sublimation, from the soot of camels' dung, is now extensively manufactured in Europe by several processes. The most usual method is to decompose sulphate of ammonia by the muriate either of soda, or of magnesia. It may also be conveniently obtained either by lixiviating the soot of coal, which contains that salt in considerable quantity; or by digging the impure carbonate of ammonia, procured by exposing bones and other animal substances to a red heat, with gypsum, so as to form an insoluble carbonate of lime, and a soluble sulphate of ammonia.

MURIATE OF BARYTA, is best formed by dissolving the carbonate of baryta, either native or artificial, in muriatic acid, diluted with three parts of water. It may also be formed by the action of muriatic acid, or the hydrosulphuret of baryta; or by heating sulphate of baryta with an equal weight of muriate of lime until fusion ensue, and then dissolving the muriate of baryta which is generated, and separating it by means of a filter from the sulphate of lime. This salt crystallizes readily in quadrangular tables, when its solution is gently evaporated. It is much employed as a re-agent in chemistry.

MURIATE OF STRONTIA.—This salt is made in the same way as the muriate of baryta, from which it is distinguished by forming prismatic crystals, by its solubility in alcohol, and by imparting a red tint to flame.

MURIATE OF LIME is formed by neutralizing muriatic acid with pure marble.

MURIATE OF MAGNESIA exists in many mineral springs, and is contained abundantly in sea-water.

Obs.—When the muriate of soda is separated from sea-water by crystallization, an uncrystallizable liquid, called *bittern*, is left, which consists chiefly of the muriate of magnesia, and is much employed in the manufacture of sal ammoniac, for decomposing the sulphate of ammonia.

MURIATE OF IRON.—When iron is dissolved in dilute muriatic acid, a muriate of the protoxide is generated, which yields pale green-coloured crystals, when the solution is concentrated by evaporation. This salt is much more soluble in hot than in cold water. It absorbs oxygen with rapidity from the air, forming an insoluble muriate of the peroxide. When boiled with a little nitric acid, a soluble muriate of the peroxide is generated, which is of a red colour, crystallizes with difficulty, deliquesces on exposure to air, and is dissolved by alcohol. It is a sesquimuriate, being composed of one atom of the peroxide, and an atom and a half of muriatic acid.

Obs.—The black oxide is also dissolved by muriatic acid, forming a dark-coloured solution, which may be considered as a mixture of the muriates of the peroxide and protoxide of iron.

HYDRIODATES.—These salts are formed by the union of hydriodic acid* with the alkalies and alkaline earths, with magnesia, and with oxides of manganese, zinc and iron: with several of the

* Hydrogen and iodine. See *Iodine*.

metallic oxides it does not enter into combination.

Ex.—On mixing the hydriodate of potassa with a salt of mercury or silver, the iodides of these metals are deposited. With the acetate of lead a yellow compound is thrown down, which is the iodide of lead.

The most direct mode of forming the hydriodates of the alkalies and alkaline earths, all of which are soluble in water, and decomposed by sulphuric and nitric acid, or by chlorine, is by neutralizing those bases with hydriodic acid. The hydriodates of iron and zinc may be made by digesting small fragments of those metals with water in which iodine is suspended.

The only hydriodates hitherto found native are those of potass and soda; of these the former is most common, although the only one of importance, and exists only in solution; for it is converted in the act of crystallizing into the iodide of potassium.

Obs.—A solution of the hydriodate of potassa is capable of dissolving a large quantity of iodine, a property which is common to all the hydriodates.

HYDROSULPHURETS OR HYDROSULPHATES.—

With the alkalies, alkaline earths, and magnesia, sulphuretted hydrogen forms soluble salts, most of which are capable of crystallizing. With the alkalies, indeed, if not with other bases, this acid unites in two proportions, forming a hydrosulphate and a bi-hydrosulphate.

As sulphuretted hydrogen is a weak acid, and is naturally gaseous, its salts are decomposed by most other acids, with the escape of sulphuretted hydrogen gas; a character by which all the hydrosulphates are easily recognized. They are

also decomposed by chlorine and iodine, with separation of sulphur and formation of a muriate or hydriodate. In a recent state, they form solutions, nearly colourless; but on exposure to the air oxygen gas is absorbed, a portion of its acid is deprived of its hydrogen, and a sulphuretted hydrosulphate of a yellow colour is generated. By continued exposure, the whole of the sulphuretted hydrogen is decomposed, water and hydrosulphurous acid being produced.

Obs.—The hydrosulphates of baryta and strontia (prepared by dissolving the sulphurets of barium and strontium in water) are sometimes used in preparing the salts of those bases. The hydrosulphates of potassa and ammonia are employed as reagents.

The hydrosulphates of potassa and of ammonia are made by transmitting a current of sulphuretted hydrogen gas into a solution of their respective bases, contained in Woulfe's apparatus, and continuing the operation as long as the gas is absorbed.

Hydroseleniates have been little examined, owing to the scarcity of selenium.

HYDROCYANATES.—These are salts formed by the union of hydrocyanic acid with alkalies, alkaline earths, and probably with several other bases; but these compounds have hitherto been studied but very imperfectly. The hydrocyanate of potassa is the best known. It is generated by the decomposition of water when the cyanuret of potassium is put into the fluid, and may be made directly by mixing hydrocyanic acid with a solution of potass. It appears only to exist in solution; for when evaporated to dryness, it is

converted into the cyanuret of potassium, a compound much less liable to spontaneous decomposition than hydrocyanic acid, and is capable of supporting a very high temperature in close vessels without change. It is deliquescent and highly soluble in water. The solution gives a green colour to violets, and has an alkaline taste, accompanied with the flavour and faint odour of hydrocyanic acid. It is decomposed by nearly all the acids, even by carbonic acid, and on this account should be preserved in well closed vessels. It acts upon the animal system in the same manner as hydrocyanic acid; and MM. Robiquet and Villerme have proposed its employment in medical practice, as being more uniform in strength, as well as being less prone to decomposition than hydrocyanic acid. (See *Magendie's Journal de Physiologie*, vol. iii.)

FERROCYANATES.—As far as is known, these salts appear to be formed in the same manner as the salts of the hydracids in general, that is, the hydrogen of the acid is in the exact proportion for forming water with the oxygen of the salifiable base with which it is united. Thus, the ferrocyanate of potassa, sometimes called triple prussiate of potassa, a perfectly neutral salt, is composed of one atom of ferrocyanic acid, which contains two atoms of hydrogen, and two atoms of potassa. With alkalies and alkaline earths, hydrocyanic acid forms soluble compounds; but it precipitates nearly all the salts of the common metals, giving use either to the ferrocyanate of an oxide, or to the ferrocyanuret of a metal.

. This salt is made on a large scale in the arts by igniting dried blood or other animal matters, such as hoofs and horns;

with potash and iron. The ferrocyanate of potassa is employed in the preparation of several compounds of cyanogen, and as a re-agent for detecting the presence of iron and other substances.

The Ferrocyanate of Baryta is prepared by digesting purified Prussian blue with a solution of pure baryta. It is soluble in water, and forms yellow crystals by evaporation. It is used in the formation of ferrocyanic acid.

. In a solution of salt of lead, the ferrocyanate of potassa throws down a white precipitate. With salts of mercury and silver, analogous compounds, likewise of a white colour, are generated. With a per-salt of copper, it causes a brownish-red precipitate, which appears to be the ferrocyanate of the peroxide of copper.

The Ferrocyanate of the Peroxide of Iron is formed by mixing the ferrocyanate of potassa with a per-salt of iron, in slight excess, and washing the precipitate with water. It is characterised by an intensely deep blue colour, and is the basis of the beautiful pigment called *Prussian blue*.*

Sulphocyanates.—The salts of the sulphocyanic acid have been chiefly studied by Mr. Porret and Berzelius, to whose writings and those of other modern chemists, we refer for the description of it, as well as for an elaborate detail of the other salts of the hydracids.

. The sulphocyanate of potassa is employed in preparing the sulphocyanic acid, and as a test for detecting the presence of the peroxide of iron.

* For an account of the ferrocyanic acid, See the Essays of Proust, Berzelius, Robiquet, in the *Annales de Chimie*, vol. lx. Also Turner's *Elements of Chemistry*, p. 509.

CHAPTER XVII.

METALS.

Q. WHAT are the general properties of metals?

A. Metals are distinguished from other substances by the following and other properties:— they are all conductors of electricity and caloric. When combined with oxygen, chlorine, iodine, or sulphur, and the resulting compounds are submitted to the action of galvanism, the metals always appear at the negative side of the battery, and for this reason they are said to be positive electrics. They are quite opaque, refusing a passage to light, though reduced to very thin leaves. They are in general good reflectors of light, and possess a peculiar lustre. Every substance in which these characters reside, may be regarded as a metal.

Q. What are the other characteristics of the metals?

A. To the above may be added their hardness, tenacity, fusibility, malleability, and ductility; but some metals are neither malleable nor ductile.

Q. How are the metals procured?

A. They are generally taken from the bowels of the earth, in a state of combination, either with other metals, with sulphur, oxygen, or with acids;* though a few of them have occasionally been found in a state of purity.

* The sulphuric, muriatic, phosphoric, and carbonic acids, are those generally found in combination with metals:

Q. By what means are the metals purified from these substances?

A. Metals are purified from their ores, by washing, roasting, fusion, &c., but the means must always be regulated by the nature of the ore to be assayed.

Obs.—The analysis of metallic ores in the great, is always performed by fire, and this is always called the *dry* way; but the more accurate analysis is effected by means of various chemical re-agents, which modern chemistry has applied to that purpose, and is termed the *moist* way. Before the time of Bergman, every kind of analysis of minerals was conducted by fire; he was the first chemist who resorted to the method of solution in acids, which is easy, simple, and effectual.

Q. How many metals are there?

A. The number of metals, the existence of which is admitted by chemists, amount to forty.

Obs.—The following table contains the names of those metals that have been procured in a state of purity, with the date of their discovery, and the names of the chemists by whom they were discovered.

Table of the Metals, &c.

Names of Metals.	By whom discovered.	Date of discovery.	Spec. Gr. 60° F.
Gold.....	Known to the ancients.....		19.257
Silver.....			10.474
Iron.....			7.788
Copper.....			8.895
Mercury.....			13.368
Lead.....			11.352
Tin.....	Described by Basil Valentine	15th cent.	7.291
Antimony ...			6.702
Zinc.....	Described by Agricola.....	1520	6.861
Bismuth	First mentioned by Paracelsus	16th cent.	9.822
Arsenic.....	By Brandt	1736	8.308
Cobalt			8.536

Names of Metals.	By whom discovered.	Date of discovery.	Spec. Gr. 60 F.
Platinum	Wood, assay master, Jamaica	1741	20.98
Nickel	Cronstedt	1751	8.279
Manganese ..	Gahn and Scheele	1774	6.850
Tungsten	M.M. D'Ehuyart	1781	17.6
Tellurium....	Müller	1782	6.115
Molybdenum	Hielm	1782	7.400
Uranium	Klaproth	1789	9.000
Titanium	Gregor	1791	5.3
Chromium ..	Vauquelin	1797	
Columbium ..	Hatchett	1802	{ 11.3 to 11.8
Palladium.. }	Dr. Wollaston	1803	
Rhodium .. }			
Iridium	{ Descotels and Smithson }	1803	
	{ Tennant..... }		
Osmium	Smithson Tennant	1803	
Cerium	Hesinger and Berzelius	1804	{ 4.489 to 4.619
Potassium .. }	Sir Humphrey Davy	1807	0.865 0.972
Sodium }			
Barium			
Strontium .. }			
Calcium.... }			
Cadmium....	Stromeyer	1818	8.604
Lithium	Arfvedson	1818	
Silicium ... }	Berzelius	1827	
Zirconium... }			

Obs.—Most of the metals are remarkable for their great specific gravity, some of them, such as gold and platinum, the densest bodies known in nature, being more than nineteen times heavier than an equal bulk of water. Great density was once supposed to be an essential character of metals; but the discovery of potassium and sodium, which are so light as to float on the surface of water, has shown that this supposition is erroneous. Some metals experience an increase of density to a certain extent when hammered, their particles being permanently approximated by the operation. On this account the specific gravity of some of the metals contained in the above table, is represented as varying between two extremes.

MALLEABILITY OF METALS.—Some metals possess the property of *malleability*, that is, they admit of being beaten into thin plates or leaves by hammering : of these are

Gold*	Lead
Silver	Zinc
Copper	Iron
Tin	Nickel
Platinum	Potassium
Palladium	Sodium
Cadmium	Frozen Mercury

The other metals are either malleable in a very small degree only, or like antimony, arsenic and bismuth, are actually brittle.

The tenacity of metals is measured by ascertaining the greatest weight which a wire of a certain thickness can support without breaking. According to the experiments of Guyton Morveau, whose results are comprised in the following table, iron, in point of tenacity, surpasses all other metals.

The diameter of each wire was 0.787th of a line.

Iron wire supports	549.25lbs.
Copper	302.278
Platinum	274.32
Silver	187.137
Gold	150.753
Zinc	109.54
Tin	34.63
Lead	27.621

* Gold surpasses all metals in malleability : one grain of it may be extended so as to cover about 52 square inches of surface, and to have a thickness not exceeding $\frac{1}{282020}$ of an inch. Dr. Wollaston has described a method by which gold wire may be obtained so fine that its

The metals differ also in degrees of hardness, though we are not aware that their exact relation to one another in this respect has hitherto been determined by experiment. In the list of hard metals may be placed titanium, manganese, iron, nickel, copper, zinc, palladium—gold, silver, and platinum are softer than these; lead is still softer, and potassium and sodium yield to the pressure of the fingers.

The properties of elasticity and sonorousness are allied to that of hardness. Iron and copper are in these respects the most conspicuous.

Many of the metals have distinctly a crystalline texture. Iron, for example, is fibrous; and zinc, bismuth, and antimony are lamellated.

Metals are sometimes obtained also in crystals; and when they do crystallize, they always assume the figure of a cube, the regular octahedron, or some form allied to it. Gold, silver, and copper, occur naturally in crystals, while others crystallize when they pass gradually from the liquid to the solid condition.

With the exception of mercury, the metals are solid at common temperatures; but they may all be liquefied by heat. And their point of fusion is very different for different metals. They differ also in volatility. Some are readily volatilized by caloric, while others are of so fixed a nature that they may be exposed to the most intense heat of a wind furnace without being dissipated in vapour. There are seven metals the volatility of

diameter shall be only $\frac{1}{3000}$ of an inch, and that 550 feet of it are required to weigh one grain. He has obtained a platinum wire so small, that its diameter did not exceed $\frac{1}{30,000}$ of an inch.—*Phil. Trans.* 1813.

which has been ascertained with certainty, namely, cadmium, mercury, arsenic, tellurium, potassium, sodium and zinc.

Obs.—The metals cannot be resolved into more simple parts, and therefore in the present state of chemistry, they must be regarded as elementary bodies. It was formerly conceived they might be converted into one another; and this notion led to the vain attempts of the alchemists to convert the baser metals into gold. The chemist has now learned that his sole art consists in resolving compound bodies into their elements, and causing substances to unite which were previously uncombined.

COMBUSTIBLE NATURE OF METALS.—Metals are of a combustible nature, that is, they are not only susceptible of slow oxidation, but under favourable circumstances, they unite rapidly with oxygen, giving rise to all the phenomena of actual combustion.

Ex.—Zinc burns with a brilliant flame when heated to full redness in the open air; iron emits vivid scintillations on being inflamed in an atmosphere of oxygen gas; and the least oxidisable metals, such as gold and platinum, scintillate in a similar manner when heated by the oxy-hydrogen blow-pipe.

Obs.—The product either of the slow or rapid oxidation of a metal, when heated in the air, has an earthy aspect, and was called a *calyx* by the older chemists, the process of forming it being expressed by the term *calcination*. Another method of oxidizing metals is by *deflagration*; that is, by mixing them with the nitrate or chlorate of potassa, and projecting the mixture into a red hot crucible.

AFFINITY OF THE METALS FOR OXYGEN.—Some of the metals unite with oxygen in one proportion only, but most of them have two or three degrees of oxidation. They differ remarkably in their relative forces of attraction for oxygen.

Ex.—Potassium and sodium are oxidized by mere exposure to the air; and they decompose water at all temperatures the instant they come in contact with it. Iron and copper may be preserved in dry air without change, nor can they decompose water at common temperatures; but they are both slowly oxidized by exposure to a moist atmosphere, and combine rapidly with oxygen when heated to redness in the open air. Iron has a stronger affinity for oxygen than copper; the former decomposes water at a red heat, whereas the latter cannot produce the same effect. Mercury is less inclined to unite with oxygen than copper. Thus it may be exposed without change to the influence of a moist atmosphere. At a temperature of 650° F., or 700°, it is oxidized; but at a red heat it is reduced to the metallic state, while the oxide of copper can sustain the strongest heat of a blast furnace without losing its oxygen. The affinity of silver is still weaker than that of mercury for oxygen; for it cannot be oxidized by the sole agency of caloric at any temperature.

Metallic oxides suffer *reduction*, that is, they may be *reduced* to the metallic state in several ways:

1. By the agency of heat alone. By this method the oxides of gold, silver, mercury, and platinum, may be decomposed.
2. By the united agency of heat and combustible matter.

Ex.—By conducting a current of hydrogen gas over the oxides of copper or of iron heated to redness in a tube of porcelain, water is generated, and the metals are obtained in a pure form. Carbonaceous matters are likewise used for the purpose with great success. Potassa and soda, for example, may be decomposed by exposing them to a white heat after being intimately mixed with charcoal in fine powder. A similar process in metallurgy for procuring the metals from their ores, the inflammable materials being wood, coke, or charcoal.

In the more delicate operations of the laboratory, charcoal and the *black-flux** are preferred.

3. By the galvanic battery.

Obs.—This is a still more powerful agent than the preceding; since some oxides, such as baryta and strontia, which resist the united influence of heat and charcoal, are reduced by the agency of galvanism.

4. By the action of deoxidizing agents on metallic solutions.

Ex.—The phosphorous acid when added to a liquid containing the oxide of mercury, deprives the oxide of its oxygen; metallic mercury subsides, and phosphoric acid is generated.

In like manner, one metal may be precipitated by another, provided the affinity of the latter for oxygen exceeds that of the former.

Ex.—When mercury is added to a solution of the nitrate of the oxide, metallic silver is thrown down, and oxide of mercury is dissolved by the nitric acid. On placing metallic copper in the liquid, pure mercury subsides, and a nitrate of the oxide of copper is formed; and from this solution metallic copper may be precipitated by means of iron.

CHAPTER XVIII.

GENERAL OBSERVATIONS ON THE METALS.

LIKE the simple non-metallic bodies, the metals may give rise to oxides or acids by com-

* When the bi-tartrate of potassa is cleft or grated with half its weight of nitre, by which a part of the charcoal is consumed, it forms *black-flux*; and when an equal weight of nitre is used, so as to oxidize all the free carbon of the tartaric acid, a pure carbonate of potassa, called *white-flux*, is procured.

bining with oxygen: the former are the most frequent products.

Many metals form oxides, which are not acidified by oxygen; whereas one metal only, arsenic, is capable of forming an acid and not an oxide. All the other metals are convertible into acids by oxygen; such as chromium, tungsten, and molybdenum, are also susceptible of yielding one or more oxides. In these instances, the acids always contain a larger quantity of oxygen than the oxides of the same metal.

The distinguishing feature of the metallic oxides is the property possessed by many of them of entering into combination with acids. All salts, those of ammonia excepted, are composed of an acid and a metallic oxide.

In some instances all the oxides of the same metal are capable of forming salts with acids, as is exemplified with the oxides of iron. More commonly, however, the protoxide is the sole *alkaline or salifiable base*.

Most of the metallic oxides are insoluble in water; but all those that are soluble have the property of giving a brown stain to the yellow turmeric paper, and of restoring the blue colour of reddened litmus.

. Chlorine has a powerful affinity for metallic substances. It readily combines with most metals at common temperatures, and the action in very many instances is so violent as to be accompanied with the evolution of light.

Ex.—When powdered zinc, arsenic or antimony, or gold leaf, is thrown into a jar of chlorine (oxy muriatic) acid, the metal is instantly inflamed. The attraction of chlorine even surpasses that of oxygen for metals.

Ex. 2.—When chlorine is brought into contact at a red heat with pure lime, magnesia, baryta, strontia, potassa, or soda,

oxygen is emitted, and a chloride of the metal is generated, the elements of which are so strongly united, that no temperature hitherto tried can separate them.

All other metallic oxides are acted upon, with few exceptions, in the same manner by chlorine; and in some cases the change takes place below ignition.

METALLIC CHLORIDES.—All the metallic chlorides are solid at the common temperature, except the bi-chlorides of tin and of arsenic, which are liquid. They are fusible by heat, assume a crystalline texture in cooling, and, under favourable circumstances, crystallize with regularity. Several of them, such as the chlorides of tin, arsenic, antimony, and mercury, are volatile, and may be sublimed without change. For the most part they are colourless, do not possess the metallic lustre, and have the aspect of salt. Two of the chlorides are insoluble in water, namely, the chloride of silver and the protochloride of mercury: the others are affected by that fluid in various ways.

Two only of the metallic chlorides, namely, those of gold and platinum, are decomposable by heat. All the chlorides of the common metals are decomposed at a red heat by hydrogen gas, muriatic acid being disengaged while the metal is set free. Pure charcoal does not affect their decomposition; but if moisture be present at the same time, muriatic and carbonic acid gases are formed, and the metal remains. Chlorine manifests a feeble affinity for metallic oxides. No combination of the kind can occur at a red heat, and no chloride of a metallic oxide can be heated to redness without decomposition. Such

compound can only be formed at low temperatures; and they are possessed of little permanency. Animal or vegetable matters are fatal to it, by giving chlorine an opportunity to exert its bleaching power; and indeed the colour is removed by the chloride potassa as readily as by a solution of chlorine in pure water.

Iodine has a strong attraction for metals; and most of the compounds it forms with them sustain a red heat in close vessels without decomposition. The action of iodine on metallic oxides, when dissolved or suspended in water, is precisely analogous to that of chlorine. On adding iodine to a solution of the pure alkalis or alkaline earths, water is decomposed, and the hydriodic and iodic acids are generated.

Sulphur, like chlorine and iodine, has a strong tendency to unite with metals: and the carbonated may be effected in various ways:

1. By heating the metal directly with sulphur.
2. By uniting a mixture of a metallic oxide and sulphur.

Obs.—The sulphurets of the common metals may be made by this process.

3. By depriving the sulphate of an oxide of its oxygen by means of heat and combustible matter; for this purpose hydrogen gas may be employed.

4. By sulphuretted hydrogen, or an alkaline hydrosulphuret.

Obs.—Almost all the salts of the common metals are decomposed when a current of sulphuretted hydrogen gas is conducted into their solutions. The salts of uranium, iron, manganese, cobalt, and nickel, are well-known exceptions; but these also are precipitated by the hydrosulphuret of ammonia.

SULPHURETS.—The sulphurets are opaque brittle solids, many of which, as the sulphurets of lead, antimony, and iron, have a metallic lustre. They are all fusible by heat, and commonly assume a crystalline texture in cooling. Most of them are fixed in the fire; but the sulphurets of mercury and arsenic are remarkable for their volatility. All the sulphurets, excepting those formed of the metallic bases of the alkalies and earth, are insoluble in water.

PROTOSULPHURETS.—Most of the protosulphurets are capable of supporting an intense heat without decomposition; but those which contain more than one atom of sulphur, lose a part of it when strongly heated. They are all, without exception, decomposed by the combined agency of heat and air or oxygen gas; and the products depend entirely on the degree of heat and the nature of the metal. The sulphuret is converted into the sulphate of an oxide, provided the sulphate is able to support the temperature employed in the operation. If this be not the case, then the sulphur is evolved under the form of sulphurous acid, and a metallic oxide is left; or if the oxide itself be decomposed by heat, the pure metal remains. The action of heat and air in decomposing metallic sulphurets is the basis of several metallurgic processes.

Obs.—It was formerly believed that many of the metallic sulphurets were compounds of sulphur and a metallic oxide—this was first shewn by Proust to be an error (See *Journal de Physique*, vol. 53); for he demonstrated that the sulphuret of iron (magnetic pyrites) as well as the common cubic pyrites or bi-sulphuret, are compounds of sulphur and metallic iron without any oxygen.

He showed the same also with respect to the sulphurets of other metals, such as those of mercury and copper. He was of opinion, however, that in some instances sulphur does unite with a metallic oxide. Thus, when sulphur and the peroxide of tin are heated together, sulphurous acid is disengaged, and the residue, according to Proust, is a sulphuret of the protoxide. It was a general belief also at that time that the compounds formed by heating sulphur with an alkali or earth are sulphurets of metallic oxides. The experiments of Vauquelin (Vol. vi. *Annales de Chimie*), the late Count Berthollet, M. Gay-Lussac, and the more recent labours of MM. Berthier and Berzelius, still more satisfactory than any of the preceding, have, however, demonstrated, that the metallic bases of the alkalis and alkaline earths agree with the common metals in their disposition to unite with sulphur. It is now certain that, whether a sulphate be decomposed by hydrogen or charcoal, or whether sulphur be ignited with an alkali or an alkaline earth, a metallic sulphuret is always the product. Direct combination between sulphur and a metallic oxide is a rare occurrence, and it may be almost doubted if it ever occurred.

Several of the metallic sulphurets occur abundantly in nature. Those most frequently met with are the sulphurets of lead, antimony, copper, iron, zinc, molybdenum, and silver.

The metallic seleniurets have so close a resemblance in their chemical relations to the sulphurets that any separate description of them is unnecessary. They may be prepared either by bringing selenium in contact with the metals

at a high temperature, or by the action of hydroselenic acid or metallic solutions.

Cyanogen has also an affinity for metallic substances. Few, however, of the cyanurets have hitherto been obtained in a separate state, excepting those of potassium, mercury, silver, lead, and palladium. The three latter are readily decomposed by a red heat,—cyanogen likewise unites with the metallic oxides.

Ex.—When hydrocyanic acid vapour is passed over pure baryta contained in a porcelain tube, and heated till it begins to be luminous, hydrogen gas is evolved, and a cyanuret of baryta, according to Gay-Lussac, is generated.*

*. * These compounds exist only in the dry state. A change is produced in them by the action of water.

Obs.—The non-metallic ingredient of each of the compounds of chlorine, iodine, sulphur, selenium, and cyanogen with metals, is the radical of a hydracid, that is, it has the property of forming with hydrogen an acid, which, like other acids, is unable to unite with metals, but which readily combines with metallic oxides. Owing to this circumstance, some difficulty arises in explaining what takes place when such substances are dissolved in water—a subject on which there are several very learned and rational opinions. Dr. Turner (See *Elem. of Chem.* p. 340), whose ideas we adopt, conceives that it may be shown in the following manner: “I have stated (p. 259) that when potassa acts upon iodine, the iodic and hydriodic acids are generated by the decomposition of water, and the solution therefore contains the iodate and hydriodate of that alkali. According to Berzelius, on the contrary, the liquid contains the iodate of potassa, and the iodide of potassium unites directly with the iodine. On this supposition, water is not decomposed at all; whereas it is demonstrable that it does undergo decomposition. The process for forming the hydro-

* Gay-Lussac also succeeded in forming cyanurets of potassa and soda by a similar process.

carburet of iodine, employed by M. Serullas, affords decisive proof that water is decomposed during the mutual action of iodine and potassa." (p. 285.)

METALLIC PHOSPHURETS.—There are several metallic phosphurets with which chemists are acquainted; and it is not improbable that, like sulphur, phosphorus is capable of uniting with all the metals. Little attention has, however, been paid to their compounds; and for the greater part of the knowledge concerning them we are indebted to the researches of Pelletier (*An. de Chim.* vol. i. and xiii.)

The most direct method of preparing the metallic phosphurets is by bringing phosphorus in contact with metals at a high temperature; or, what amounts to the same thing, by igniting metals in contact with phosphoric acid and charcoal. Many of the phosphurets may be formed by passing a current of phosphuretted hydrogen gas over metallic oxides heated to redness in a porcelain tube. Water is generated, and a phosphuret of the metal remains.

Phosphorus also unites with some of the metallic oxides. The phosphurets of lime and baryta, for instance, may be made by conducting the vapour of phosphorus over those earths at a red heat.

The only metallic carburets of importance are those of iron.

Hydrogen unites with few metals. The only metallic hydrogurets known are those of zinc, potassium, arsenic, and tellurium..

CHAPTER XIX.

CLASSIFICATION OF THE METALS.

THE number of the metals being considerable, in order to facilitate their study as much as possible, we have here adopted the arrangement of M. Thenard, with the slight modifications therein of Dr. Henry in his "Elements of Experimental Chemistry:" hence they are divided into the two following classes:—

Class I.—Those metals whose oxides cannot be reduced to the metallic state by the sole action of heat.

Class II.—Those metals whose oxides are reducible by heat only.

Obs.—The metals of the first class were formerly called *base* or *imperfect* metals, in contradistinction to gold, silver, and mercury, which were termed the noble or perfect metals.

As the metals contained in the first class are numerous, and differ from one another in the degree of their affinity for oxygen, they may be subdivided into four orders:—

Order 1.—Metals which decompose water at common temperatures. These are six in number, viz. *as*

- | | | |
|---------------|-------------|---------------|
| 1. Potassium. | 3. Lithium. | 5. Strontium. |
| 2. Sodium. | 4. Barium. | 6. Calcium. |

The protoxides of the three first are distinguished by their causticity and solubility in water; and by possessing alkaline properties in an eminent degree. They are called *alkalies*, and their metallic bases are frequently termed

the *alkaline metals*. The protoxides of the other three are commonly called *alkaline earths*; because they approach, both in appearance and their sparing solubility in water, to the nature of the earths, though they possess the acid taste and alkaline re-action of the pure alkalies. The metals of this order are sometimes called *metalloids*, an incorrect expression, and now greatly abandoned. A body either does or does not possess the essential properties of a metal. If it does possess them, it is to all intents and purposes a real metal.

Order 2.—Of this order are those metals which are supposed to be analogous to the preceding; but the exact nature of them has not been determined. They are six in number, viz.:—

- | | | |
|---------------|--------------|---------------|
| 1. Magnesium. | 3. Yttrium. | 5. Zirconium. |
| 2. Glucinum. | 4. Aluminum. | 6. Silicum. |

Their oxides have a white colour, an earthy aspect, and are sparingly soluble in water. They are denominated *earths*, and their metallic bases are sometimes called *earthy metals*.

Order 3.—Consists of metals which decompose water at a red heat. They are five in number, viz.:—

- | | | |
|---------------|-------------|---------------|
| 1. Manganese. | 3. Cadmium. | 5. Strontium. |
| 2. Zinc. | 4. Tin. | |

Order 4.—Consists of metals which do not decompose metals at any temperature. Of these there are fifteen, viz.:—

- | | | |
|----------------|---------------|----------------|
| 1. Arsenic. | 6. Uranium. | 11. Titanium. |
| 2. Molybdenum. | 7. Columbium. | 12. Bismuth. |
| 3. Chromium. | 8. Nickel. | 13. Copper. |
| 4. Tungsten. | 9. Cobalt. | 14. Tellurium. |
| 5. Antimony. | 10. Cerium. | 15. Lead. |

Class II.—The second class consists only of eight metals, the oxides of which are decomposed by a red heat: these are

- | | | |
|-------------|---------------|-------------|
| 1. Mercury. | 4. Platinum. | 7. Osmium. |
| 2. Silver. | 5. Palladium. | 8. Iridium. |
| 3. Gold. | 6. Rhodium. | |

Rem.—Having concluded the general properties of metals, the history of each individual will be more beneficially consulted in more extensive works: before, however, we leave the subject entirely, we shall devote a short space to the consideration of alloys.

CHAPTER XX.

METALLIC COMBINATIONS.

THE compounds are called *alloys*; and to those alloys in which mercury is a constituent, the term *amalgam* is applied. It is probable that each metal is capable of combining in one or more proportions with every other metal; and on this supposition the number of alloys would be exceedingly numerous. As this branch of chemistry has hitherto been cultivated with less zeal than most other departments of the science, is still limited, and our knowledge concerning it imperfect, we shall only allude to those alloys to which some particular interest is attached.

Metals do not combine with one another in their solid state; a circumstance which may be attributed to the influence of chemical affinity being counteracted by the force of cohesion. It is necessary, at least, to liquefy one of them,

looking-glasses; and an amalgam made of one part of lead, one of tin, two of bismuth, and four parts of mercury, is used for silvering the inside of hollow glass globes. This amalgam is solid at common temperatures; but is fused by a slight degree of heat. The amalgam of zinc and tin, used for promoting the action of the electrical machine, is made by fusing one part of zinc with one of tin, and then agitating the liquid mass with two parts of mercury placed in a wooden box.

Obs.—Mercury shows very little disposition to unite with iron, and, on this account, it is usually preserved in iron bottles.

The amalgam of silver is a mineral production. Gold unites with remarkable facility with mercury, forming a white-coloured compound. An amalgam composed of one part of gold to equal of mercury, is employed in gilding brass. The brass, after being rubbed with the nitrate of mercury, in order to give it a thin film of quicksilver, is covered with the amalgam of gold, and then exposed to heat for the purpose of expelling the mercury.

Alloys of Arsenic.—Arsenic has a tendency to render the metals, with which it is alloyed, both brittle and fusible. It has the property of destroying the colour of gold and copper. An alloy of copper, with a tenth-part of arsenic, is so very similar in appearance to silver, that it has been substituted for it. The presence of arsenic in iron has a very pernicious effect; for even though in a small proportion, it renders the iron brittle, especially when heated. The alloy of tin and arsenic is employed for forming arseniuretted hydrogen gas, by the action of muriatic acid. The tin of commerce sometimes contains a

minute quantity of this alloy. An alloy of platinum, with ten-parts of arsenic, is fusible at a heat a little above redness, and may, therefore, be cast in moulds. On exposing the alloy to a temperature gradually increasing in open vessels, the arsenic is oxidized and expelled, and the platinum recovers its purity and infusibility.

Alloys of Tin, Lead, Antimony, and Bismuth.—

Tin and lead readily unite when fused together. Equal parts of these metals constitute an alloy, which is more fusible than either separately, and is the common solder of the glaziers.

With small quantities of antimonies, tin, copper, and bismuth form the best kinds of pewter. Inferior sorts contain a large proportion of lead.

An alloy of three parts of lead to one of antimony constitutes the substance of which printers' types are composed.

*Alloys of Copper.—*Copper with tin forms several valuable alloys, which are characterized by their sonorousness. Bronze is an alloy of copper with about a ten per cent. of tin, with small quantities of other metals which are not essential to the compound. Cannons are cast with a similar kind of alloy. The best bell-metal is composed of eighty parts of zinc and twenty of tin: the Indian gong, celebrated for the richness of its tones, contains copper and tin in this proportion.

Copper and zinc unite in several proportions, forming alloys of great importance in the arts. The best brass consists of four parts of copper to one of zinc; and when the latter preponderates, compounds are generated called

Lombac, Dutch gold, and pinchbeck. The art of tinning copper consists in covering that metal with a thin layer of tin, in order to protect its surface from rusting.

Alloys of Steel.—Messrs. Stodart and Faraday ascertained that silver combines with steel, forming an alloy which, although it contains only 1-500th of its weight of silver, is superior to the Indian steel called *Wootz*, or the best cast steel in hardness.

Alloys of Silver.—Silver is capable of uniting with other metals, and suffers greatly in malleability and ductility by their presence. It may contain a great quantity of copper without losing its white colour. The standard silver for coinage contains about 1-13th of copper, which increases its hardness, thus rendering it fitter for coins and other purposes.

Alloys of Gold.—The presence of other metals in gold has a remarkable effect in impairing its malleability and ductility. The metals which possess this property in the greatest degree, are bismuth, lead, antimony and arsenic. Gold coins contain about 1-12th of copper.

CHAPTER XXI.

ATTRACTION, REPULSION, AND CHEMICAL AFFINITY.

" For this the moon thro' heaven's blue concave glides
And into motion charms the expanding tides ;
While earth impetuous round her axle rolls,
Exalts her wat'ry zone, and sinks the poles."

Falconer.

Q. WHAT is attraction ?

A. It is that unknown force which causes bodies to approach each other.

Q. What are the most obvious instances of attraction ?

A. The gravitation of bodies to the earth ; that of the planets towards each other ; and the attraction of electricity and magnetism.

Q. What other instances of attraction are we acquainted with.

A. Attraction likewise subsists between the particles of bodies ; and it is this kind of attraction which comes under the more immediate notice of the chemist.

Q. How is this kind of attraction defined in chemical language ?

A. Whenever the force of attraction operates between particles of the same species, it is called the attraction of *cohesion*,* or the attraction of *aggregation* ; but between the particles of different substances, it is then called the attraction of composition, or chemical affinity.

* It is from the attraction of *cohesion* that a drop of water is always spherical, and that small particles of quicksilver are constantly of a globular figure.

Exp.—If common flour of sulphur and potass be mixed and thrown into water, the sulphur will separate and the potass be dissolved; but if they be previously melted together, the union will then be so perfect, that the compound will be completely soluble. The object of this experiment is to show that chemical affinity has no sensible action on the mere elementary particles of bodies.

2. A piece of loaf sugar broken into fine powder, or water in the state of vapour, is said to have attraction of aggregation broken; but the smallest atom of the powder is still sugar; and the most trifling portion of the vapour is still water. In order to exemplify the latter kind of attraction (chemical affinity), a little caustic soda may be put into a glass, and muriatic acid added to it. Both these are corrosive substances; but the compound resulting from them will be found to be our common table salt,—a muriate of soda. Here we have an instance of two heterogeneous bodies producing, by their action on each other, a distinct substance, possessing the properties of *neither* of the bodies which compose it.

If several salts be dissolved in the same water, each particle, when they crystallize, will find its own kind, by a sort of innate polarity.

Ex.—Dissolve separately equal weights of sulphate of copper and crystals of carbonate of soda in sufficient quantities of boiling water: pour them together while hot into a flat pan, and when the water has evaporated a little, and the whole is suffered to cool, the salts will shoot; the sulphate of copper in *blue*, the soda in *white* crystals, similar in condition to what they were before they were dissolved.

Obs.—Those substances which are capable of uniting are said to have a chemical affinity for each other; those which do not form a chemical union, are said to have no affinity.

Chemical attraction can only exist between the particles of opposite and distinct substances, and this species of attraction is exerted with different force, according to the nature of such

substances, and frequently in proportion to the mass. Most bodies combine only in certain proportions: *e. g.* oxygen and hydrogen combine also in one proportion, and ammonia is the result. New combinations acquire new properties: *e. g.* If nitrate of ammonia and sulphate of soda, both in crystals, be rubbed together in a stone mortar in equal proportions, the mixture will be converted into a fluid.

Q. How are the different kinds of chemical attraction distinguished?

A. The different kinds of chemical attraction are distinguished into

1. Simple attraction.
2. Compound attraction.
3. Disposing attraction.

Simple attraction is when two substances unite merely in consequence of their mutual attraction; they are then said to combine by virtue of simple attraction or affinity: *e. g.* Take a portion of the acetate of soda, pour muriatic acid upon it in a retort, and distil it to dryness. The acetic acid will be expelled, and the muriatic acid will be found in combination with the soda, united so strongly that the most intense heat will not be able to separate it. This is owing to the soda having a greater affinity for muriatic acid than it had for the acetic.

Again: If a portion of nitric acid be now added to the muriate of soda, and heat applied, the muriatic acid will be again disengaged, and the nitric acid will be in possession of the soda.

Lastly: If to the nitrate of soda sulphuric acid be added, and these exposed to a due degree of heat, the nitric acid will be expelled, and the sulphuric acid will be in possession of the

alkali, forming a true sulphate of soda. These changes all take place in consequence of chemical attraction. By this attraction acetic acid combines with soda, and forms a salt called acetate of soda; but muriatic, nitric, and sulphuric acid have each of them a stronger affinity for soda, and their respective affinities are in the order in which they have been named.

Compound affinity is the action of two compound substances whereby they mutually decompose each other, and produce two or more compounds.

Ex.—If into a solution of sulphate of ammonia there be poured nitric acid, no decomposition is produced, because the sulphuric acid has a stronger affinity than nitric acid for ammonia. But if a solution of nitrate of potass be poured in, we obtain by evaporation two new bodies, viz., *sulphate of potass* and *nitrate of ammonia*. In this case, the sulphuric of the sulphate of ammonia attracts the potass of the nitrate of potass, at the same time that the ammonia attracts the nitric acid; and to the agency of these united affinities the double decomposition must be attributed.

Disposing affinity takes place when bodies, which apparently have no tendency to unite themselves, combine in consequence of the addition of another substance: the union is then said to be produced by means of *disposing affinity*.

Q. What other terms are employed on the subject of chemical affinities?

A. There are two other terms, called *quiescent* attractions and *divellent* attractions.

Q. What do you mean by *quiescent* attractions?

A. By *quiescent* attractions is understood that, when two or more bodies are presented to each other, the attractions which tend to

preserve their original arrangement of parts are denominated the *quiescent* affinities.

Ex.—If a few drops of the nitrate of silver be poured into a solution of the muriate of soda, two new substances will be formed, namely, nitrate of soda, and muriate of silver; the latter of which being insoluble in water, will be precipitated. In this experiment the affinity of the nitric acid for the silver, and the muriatic acid for the soda, are the *quiescent* affinities; whereas the affinity of the nitric acid to the soda, and the muriatic acid to the silver, are the *divellent* affinities. Hence, no new arrangement of parts in any mixture can take place, unless *divellent* attraction exist.

Q. What is meant by *divellent* affinities?

A. *Divellent* affinities are those attractions which tend to destroy the original compound, and to form new arrangements.

Obs.—From all that has hitherto been explained, the study of chemical attractions seems to be beyond doubt the most important part of chemistry; for it is only through a knowledge of the attractions which different substances have for each other, that a complete analysis of the productions of nature is to be attained. With this object in view, the student should study as well as practise the various tables of affinities of Bergman, Pearson, and others. The order in which these decompositions take place, many of which that occur in chemistry are instances of elective affinity, has been expressed by Geoffrey in the following table:

Sulphuric.

—
Baryta.

Strontia.

Potash.

Soda.

Lime.

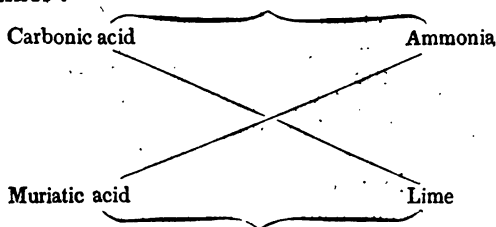
Ammonia.

Magnesia.

This table is intended to show, first, that sulphuric acid has an affinity for the substances placed below the horizontal line, and can therefore unite separately with each of them; and, secondly, that the base of the salts so formed will be separated from the acid by adding any of the alkalies or earths which stand above it in the columns. For instance, ammonia will separate magnesia, lime ammonia, and potash lime; but none of them can withdraw baryta from the sulphuric acid, nor can ammonia or magnesia decompose the sulphate of lime, though strontia or baryta will do it. Bergman conceived that these decompositions were solely determined by chemical attraction, and that consequently the order of decomposition represented the comparative forces of affinity; and this view, from the simple and natural explanation it afforded of the phenomenon, was for a time generally adopted. But Bergman was in error. It does not necessarily follow, because lime can separate ammonia from sulphuric acid, that the lime has a greater attraction for the acid than the volatile alkali. Other causes are in operation which modify the action of affinity to such a degree, that it is impossible to discover how much of the effect is owing to that power. It is conceivable that the ammonia may in reality have a stronger attraction for sulphuric acid than lime, and yet the lime, from the great influence of disturbing causes, might succeed in decomposing the sulphate of ammonia. To Berthollet is due the honour of pointing out the fallacy of Bergman's opinion. He was the first to show, that the relative force of chemical attraction cannot always be determined by observing the order in which

substances separate each other when in combination, and that the tables of Geoffrey are merely tables of decomposition, and not of affinity.

Affinity is the cause of still more complicated changes than any of those already considered. In a case of single elective affinity, three substances only are present, and two affinities are in play. But it frequently happens that two compounds are mixed together, and four different affinities brought into action. The changes that may or do occur under these circumstances, are most conveniently studied by aid of a diagram,—a method first employed by Dr. Black, and since generally practised. For example, in mixing together a solution of the carbonate of ammonia and muriate of lime, their mutual action may be represented in the following manner:—



EXPLANATION.—Each of the acids has an attraction for both of the bases, and hence it is possible either that the two salts should continue as they are, or that an interchange of principles should ensue, giving rise to two new compounds. According to the views of Bergman, the result is dependant solely on the comparative strength of affinities. If the affinity of the carbonic acid for the ammonia, and of the muriatic acid for the

lime, be added to that of the muriatic acid for ammonia, then will the two salts experience no change whatever; but if the latter affinities preponderate, then, as does actually happen in the present instance, both the original salts will be decomposed, and two new ones generated. Two decompositions and two combinations take place, being an instance of what is called double elective affinity. Mr. Kirwan applied the terms quiescent and divellent to denote the tendency of the opposing affinities, the action of the former being to prevent a change, the latter to produce it.

The doctrine of double elective affinity was attacked on the same ground by Berthollet, and with the same success as in the case of single elective attraction. He succeeded in proving that the effect cannot always be ascribed to the sole influence of affinity. For, taking the example already adduced, if the carbonate of ammonia decompose the muriate of lime by the mere force of a superior attraction, it is manifest that the carbonate of lime ought never to decompose the muriate of ammonia. But if these two salts are mixed in a dry state and exposed to heat, double decomposition does take place, carbonate of ammonia and muriate of lime being formed; and, therefore, if the change in the first example was produced by chemical attraction alone, that in the second must have occurred in direct opposition to that power. It does not, however, follow, because the result is sometimes determined by modifying conditions, that it must always be so. We apprehend that the decomposition of the solid cyanuret of mercury by sulphuretted hydrogen gas, which takes place even at

a low temperature, cannot be ascribed to any other cause than a preponderance of the divellent over the quiescent affinities.

CHAPTER XXII.

CHANGES THAT ACCOMPANY CHEMICAL AFFINITY.

THE loss of properties experienced by the combining substances, and the acquisition of new ones by the product of their combination, are the leading circumstances which characterize chemical action. The change of property is sometimes inconsiderable. In a solution of sugar or salt in water, and in mixtures of water with alcohol or sulphuric acid, the compound retains so much of the character of its constituents that there is no difficulty in recognizing their presence. But more generally the properties of one or both disappear. No one could guess, *à priori*, that water is a compound body, much less that it is composed of two gases, oxygen and hydrogen, neither of which when uncombined has ever been compressed into a liquid. Hydrogen is one of the most inflammable substances in nature, and yet water cannot be set on fire: oxygen, on the contrary enables bodies to burn with great brilliancy, and yet water extinguishes combustion. The alkalies and earths were regarded as simple till Sir H. Davy proved them to be compounds, and cer-

certainly they evince no sign whatever of containing oxygen gas and a metal.

Numerous examples of a similar kind are afforded by the action of acids and alkalies on each other. For instance, sulphuric acid and potash are highly caustic. The former is intensely sour, reddens the blue colour of vegetables, and has a strong affinity for alkaline substances; the latter has a pungent taste, converts the blue colour of vegetables to green, and combines readily with acids. On adding these principles cautiously to one another, a compound results, called a neutral salt, which does not in any way affect the colouring matter of plants, and in which the other distinguishing features of an acid and an alkali can no longer be perceived. They appear to have destroyed the properties of each other, and hence they are said to neutralize one another.

The other phenomena that accompany chemical action are changes of density, temperature, form and colour.

Of the conditions which modify, or are capable of promoting or counteracting the tendency of chemical attraction, the following are the most important:—cohesion, elasticity, quantity of matter, and gravity. To these may be added the agency of the imponderables.

Of all chemical substances, our knowledge of the relative degrees of attraction of the acids and alkalies for each other is the most uncertain. Their action on one another is affected by so many circumstances, that it is in most cases impossible, with certainty, to refer any effect to its real cause. The only remedies that have hitherto been devised for remedying this defect, are those

of Berthollet and Kirwan. Both of them are founded on the capacities of saturation, and the objections that have been urged to the rule suggested by the first philosopher, applies equally to that proposed by the second. But this uncertainty is of no great consequence in practice.

CHAPTER XXIII.

OXYGEN.

OXYGEN gas may be obtained from several sources. The peroxides of lead, manganese, and mercury, and the chlorate of potash, all yield it in large quantity when they are exposed to a red heat. The substances commonly employed for the purpose are the peroxide of manganese and the chlorate of potash. It may be procured from the former in two ways, either by heating it to redness in a gun-barrel, or in a retort of iron or earthenware; or by putting it into a flask with half its weight of concentrated sulphuric acid, and heating the mixture by means of a lamp.

Properties of Oxygen Gas.—Oxygen gas is colourless, has neither taste nor smell, is not chemically affected by the imponderables, refracts light very feebly, and is a non-conductor of electricity. It is the most perfect negative electric that we possess, always appearing at the positive pole when any compound which contains it is exposed to the action of galvanism.

It emits light, as well as heat, when suddenly and forcibly compressed. It is heavier than atmospheric air. Chemists have differed as to its precise weight; but the late experiments of Dr. Thompson leave little doubt of the accuracy of Dr. Proust's estimate,* which is that 100 cubic inches of oxygen, when the thermometer is at 60° F. and the barometer stands at 30 inches, weigh 33.888 grains; and its specific gravity must be 1.1111.

Oxygen gas is very sparingly absorbed by water, 100 cubic inches of that liquid dissolving only three or four of the gas. It has neither acid nor alkaline properties; for it does not redden or turn green the blue vegetable colours, nor does it show any disposition to unite either with acids or alkalies.

The act of combining with oxygen is called *oxidation*, and the bodies, after having united with it, are said to be *oxidized*. The compounds thus formed are divided by chemists into acids and oxides. The first division includes those compounds which possess the general properties of acids; and the second comprehends those in which that character is wanting.

PHENOMENA OF OXIDATION.—These are variable. Oxidation is sometimes produced with great rapidity, and with an evolution of heat and light: for instance, ordinary combustion is nothing more than rapid oxidation; and all inflammable or combustible matters derive their power of burning in the open air from their affinity for oxygen. On other occasions it takes

* See Vol. vi. (old series) of the *Annals of Philosophy*.

place slowly, and without any appearance either of heat or light, as exemplified by the rusting of iron when exposed to a moist atmosphere. Different as these processes appear, oxidation is the result of both; and both are owing to the same circumstance, namely, to the presence of oxygen in the atmosphere. All substances that are capable of burning in the open air, burn with far greater brilliancy in oxygen. A piece of wood on which the least spark of light is visible, bursts into flame the moment it is put into a jar of oxygen; lighted charcoal emits beautiful scintillations; and phosphorus burns with so powerful and dazzling a light that the eye cannot bear its impression. Even iron and steel, which are not commonly ranked among the inflammables, undergo a rapid combustion in oxygen gas.

The changes by which these phenomena are accompanied are no less remarkable. When a lighted taper, for instance, is put into a vessel of oxygen gas, it burns for a while with increased splendour; but the size of the flame soon begins to diminish, and if the mouth of the jar be properly secured by a cork, the light, in a short time, will entirely disappear. The gas has now lost its characteristic property; for a second lighted taper immersed in it is instantly extinguished. This result is general. The burning of one body in a given portion of oxygen unfits it for supporting the combustion of another; and the cause is manifest. The combustion is produced by the combination of inflammable matter with oxygen. The quantity of free oxygen, therefore, diminishes during the process, and is at length exhausted. The

burning of all bodies, however inflammable, must then cease, because the presence of oxygen is necessary to its continuance. For this reason oxygen gas is called a supporter of combustion.

Oxygen gas also often loses its gaseous form as well as its properties.

Ex.—If phosphorus or iron be burned in a jar of pure oxygen over water or mercury, the disappearance of the gas becomes obvious by the ascent of the liquid, which is forced up by the pressure of the atmosphere, and fills the vessel. On the contrary, the oxygen sometimes suffers only a partial diminution of volume, or even undergoes no change of bulk at all, as exemplified by the combustion of the diamond.

The changes experienced by the burning body are equally remarkable. While the oxygen loses its power of supporting combustion, the inflammable substance lays aside its combustibility. It is now an oxidized body, and cannot be made to burn even by the aid of the purest oxygen. It has also acquired additional weight. It is an error to suppose that bodies lose any thing while they burn. The materials of our fire and candles do indeed disappear, but they are not destroyed. Although they fly off in the gaseous form, and are commonly lost to us, it is not difficult to collect and preserve all the pendants of combustion. When this is done with the requisite care, it is constantly found that the combustible matter weighs more after than before combustion; and that the increase in weight is exactly equal to the quantity of oxygen which has disappeared during the process.

Oxygen is absolutely necessary to respiration. No animal can live in an atmosphere which does not contain a certain portion of uncombined oxygen; for an animal soon dies if put into a portion of air from which the oxygen has been previously removed by a burning body. It may therefore be anticipated that oxygen is consumed during respiration. If a bird be confined in a limited quantity of atmospheric air it will at first feel no inconvenience; but as a portion of oxygen is withdrawn at each inspiration, its quantity rapidly diminishes, so that respiration soon becomes laborious, or soon ceases entirely. If another bird be then introduced into the same air, it will die in the course of a few seconds; or, if a lighted candle be immersed in it, its flame will be extinguished. Respiration and combustion therefore have the same effect. An animal cannot live in an atmosphere which is unable to support combustion; nor can a candle burn in air which is unfit for respiration.

CHAPTER XXIV.

HYDROGEN.

THE nature and leading properties of hydrogen gas were first pointed out by Mr. Cavendish. It is a colourless gas, and, when perfectly pure, has neither smell nor taste. It is a powerful refracter of light: like oxygen, it cannot be resolved into more simple parts, and, like that

gas, it has hitherto resisted all attempts to compress it into a liquid. It is the lightest body in nature, and, consequently, is the best material for filling balloons. It is exactly sixteen times lighter than oxygen, and, therefore, 100 cubic inches of it at 60° F. and 30 bar., must weigh $\frac{33.888}{16}$, or 2.118 grains. Its specific gravity is consequently 0.0694.

Hydrogen does not change the blue colour of vegetables. It is sparingly absorbed by water, 100 cubic inches of which dissolves about $1\frac{1}{2}$ of the gas. It cannot support respiration, for an animal soon perishes when confined in it. Death ensues from the want of oxygen, rather than from any noxious quality of the hydrogen, since an atmosphere composed of a due proportion of oxygen and hydrogen may be inhaled without any inconvenience.

Hydrogen is inflammable in an eminent degree, though, like other combustibles, it requires the aid of a supporter for enabling its combustion to take place. This is exemplified in the experiment above alluded to, in which the gas is kindled by the flame of the candle, but burns only when it is in contact with the air. Its combustion, when conducted in this manner, goes on tranquilly, and is attended with a yellowish-blue flame and a very feeble light. The phenomena, however, differ, when the hydrogen is previously mixed with a due quantity of atmospheric air. The approach of flame not only sets fire to the gas near it, but the whole is kindled at the same instant; a flash of light passes through the mixture, which is followed by a violent explosion. The best proportion for the experiment is two measures of hydrogen, to five or six of air,

particularly when the gases are mixed together in the ratio of one measure of oxygen to two of hydrogen.

Oxygen and hydrogen gases do not combine at ordinary temperatures; they may, therefore, be kept in a state of mixture without even gradual combination taking place between them. The latter may be set on fire, when in contact with air or oxygen gas, by flame, by a solid body heated to bright redness, and by the electric spark.

Exp.—If a jet of hydrogen be thrown upon recently prepared spongy platinum, this metal almost instantly becomes red hot, and then sets fire to the gas;—a recent discovery by professor Dobereiner of Jena.

Obs.—The power of flame and electricity in causing a mixture of hydrogen with an air or oxygen gas to explode, is limited. Mr. Cavendish found that flame occasions a very feeble explosion when the hydrogen is mixed with nine times its bulk of air; and that a mixture of four measures of hydrogen to one of air, does not explode at all. An explosive mixture formed of two measures of hydrogen to one of oxygen, explodes from all the causes above enumerated. M. Biot found that sudden and violent compression likewise causes an explosion, apparently from the heat emitted during the operation; for an equal degree of condensation does not produce the same effect. A large quantity of caloric is evolved during the combustion of hydrogen gas.

Water is the sole product of the combustion of hydrogen gas. For this important fact we are indebted to Mr. Cavendish, who demonstrated it by burning oxygen and hydrogen gases in a dry glass vessel, when a quantity of pure water was generated exactly equal in weight to that of the gases which had disappeared. This experiment, which is the synthetic

proof of the composition of water, was afterwards made on a much larger scale in Paris, by Vauquelin, Fourcroy, and Sequin. Lavoisier first demonstrated its nature analytically, by passing a known quantity of watery vapour over metallic iron heated to redness. Hydrogen gas was disengaged, the metal in the tube was oxidized, and the weight of the former, added to the increase which the iron had experienced from combination with oxygen, exactly corresponded to the quantity of water which had been decomposed.

There are two ways by which hydrogen gas may be easily procured. The first, already mentioned, consists in passing the vapour of water over metallic iron heated to redness. This is done by putting iron-wire into a gun-barrel open at both ends, to one of which is attached a retort containing pure water, and to the other a bent tube. The gun-barrel is placed in a furnace, and when it has acquired a full red heat, the water in the retort is made to boil briskly. The gas, which is copiously disengaged as soon as the steam comes in contact with the glowing iron, passes along the bent tube, and may be collected in convenient vessels, by dipping the free extremity of the tube into the water of a pneumatic trough. The second and most convenient mode consists in putting pieces of iron or zinc into dilute sulphuric acid, formed of one-part of strong acid to four or five of water. Zinc is generally preferred.

Obs.—The hydrogen obtained in these processes is not absolutely pure. The purest iron-wire contains traces of charcoal, in consequence of which the gas formed by its means, is apt to contain carbonic acid, and most probably carburated hydrogen. The zinc of commerce contains both charcoal and

sulphur, so that in addition to the gases first mentioned, the hydrogen derived from this source is contaminated with sulphuretted, and, perhaps, with carburetted hydrogen. A little metallic zinc is also contained in it, apparently in combination with hydrogen. All these impurities, carburetted hydrogen excepted, may be removed by passing the hydrogen through a solution of pure potash. To obtain hydrogen of great purity, distilled zinc should be employed.

* * For the methods of preparing the deutoxide of hydrogen, discovered by M. Thenard, in the year 1818, and the peroxide of the same gas; see his original Memoir in the *Annales de Chimie et de Physique*, vol. viii. and x.; *Annals of Philosophy*, vol. xiii. and xiv.; and M. Thenard's *Traité de Chimie*.

CHAPTER XXV.

NITROGEN.

THE existence of nitrogen gas, as distinct from any other gaseous substance, was first noticed by the late Dr. Rutherford, in 1772. Lavoisier, who called it azote, because it is unable to support the respiration of animals, discovered that it is a constituent part of the atmosphere in 1775, and the same discovery was made soon after, or about the same time, by Scheele.

Pure nitrogen is a colourless gas, wholly devoid of smell and taste. It does not change the blue colour of vegetables, and is distinguished by other gases more by negative characters than by any striking quality. It does not support combustion; but, on the contrary, ex-

tinguishes all burning bodies that are immersed in it. No animal can live in it; still it exerts no injurious action either on the lungs or on the system at large; the privation of oxygen being the sole cause of death. It is not inflammable, though, under favourable circumstances, it may be made to unite with oxygen. Water, when deprived of air by ebullition, takes up about one and a-half per cent. of it. Its specific gravity is 0.9722, on the assumption that air consists of one measure of oxygen to four of nitrogen, and that 1.1111 is the specific gravity of oxygen gas; and, therefore, 100 cubic inches of it at the mean temperature and pressure, will weigh 29,652 grains.

Nitrogen gas is easily prepared by burning a piece of phosphorus in a jar full of air inverted over water. The strong affinity of phosphorus for oxygen, enables it to burn till the whole of that gas is consumed. The product of the combustion, phosphoric acid, is at first diffused through the residue in the form of a white cloud; but as this substance is rapidly absorbed by water, it disappears entirely in the course of half an hour. The residual gas is nitrogen, containing a small quantity of carbonic acid and vapour of phosphorus, both of which may be removed by agitating it briskly with a solution of pure potash.

Several other substances may also be employed for withdrawing the oxygen from atmospheric air. A solution of the protosulphate of iron, charged with the deutoxide of nitrogen, absorbs the oxygen in a few minutes. A stick of phosphorus produces the same effect in twenty-four hours, if exposed to a temperature of 60° F. A

solution of the sulphuret of potash or of lime acts in a similar manner; and a mixture of equal parts of iron-filings and sulphur, made into a paste with water, may be employed with the same intention. Both these processes, however, are inconvenient from their slowness.

Nitrogen gas may likewise be procured by exposing a mixture of fresh muscle and nitric acid of specific gravity 1.20 to a moderate temperature. A large quantity of gaseous matter is evolved with effervescence, which is nitrogen mixed with carbonic acid. The latter must be removed by agitation with lime water; but the residue still retains a peculiar odour, indicative of the presence of some volatile principle, which cannot be wholly separated from it. The theory of this process is rather complex, and may be more conveniently studied in more elaborate works.

COMPOUNDS OF OXYGEN AND NITROGEN.—

There are five compounds of nitrogen and oxygen with which chemists are acquainted, whose composition, as deduced from the researches of Gay-Lussac, Dr. Henry, and Sir H. Davy, is as follows:—

	BY VOLUME.		BY WEIGHT.	
	Nitrogen.	Oxygen.	Nitrogen.	Oxygen.
Nitrous oxide....	100	50	14	8
Nitric oxide.....	100	100	14	16
Hyponitrous acid.	100	150	14	24
Nitrous acid.....	100	200	14	32
Nitric acid	100	250	14	40

Obs.—The first of these compounds, as containing the smallest quantity of oxygen, is presumed to consist of one atom of each element. The atomic weight of nitrogen, that of oxygen being eight, will therefore be fourteen. The other four compounds must consequently be composed of one atom

of nitrogen, united in the second with two, in the third with three, in the fourth with four, and in the fifth with five atoms of oxygen.

PROTOXIDE OF NITROGEN.—The protoxide of nitrogen was discovered by Priestley, who named it *dephlogisticated nitrous air*. Sir H. Davy called it *nitrous oxide*; but according to the principles of chemical nomenclature, its proper appellation is protoxide of nitrogen.

This gas may be formed by exposing the nitric oxide for some days to the action of iron filings, or other substances which have a strong affinity for oxygen. But the most convenient means of procuring it is by the means of the nitrate of ammonia. When this salt is exposed to a temperature of 400° or 500° F. it liquefies, bubbles of gas begin to rise from it, and in a short time a brisk effervescence ensues, which continues till the whole of the salt disappears.

Obs.—The nitrate of ammonia should be contained in a glass retort, and the heat applied by means of a lamp placed at such a distance below it as to maintain a moderately rapid evolution of gas.

The protoxide of nitrogen is a colourless gas; it does not affect the blue vegetable colours, even when mixed with atmospheric air; it is a supporter of combustion, most substances burning in it with much greater energy than in the atmosphere. When a recently extinguished candle with a very red wick is introduced into it, the flame is instantly restored. Phosphorus, if previously kindled, burns in it with great brilliancy. With an equal bulk of hydrogen it forms a mixture which explodes violently by the electric spark or by flame. The protoxide is decomposed; the combustible matter unites with

its oxygen, and the nitrogen is set free. The protoxide of nitrogen suffers decomposition when a succession of electric sparks are passed through it. A similar effect is caused by conducting it through a porcelain tube heated to incandescence. In both instances it is resolved into nitrogen, oxygen, and nitrous acid. Sir H. Davy discovered that the protoxide of nitrogen may be taken into the lungs with safety, and that it supports respiration for a few minutes. Its action on the system, when inspired, is very remarkable. A few deep inhalations of it are followed by most agreeable feelings of excitement, similar to the early stages of intoxication; which is evinced by a strong propensity to laughter, by a rapid flow of vivid ideas, and an unusual disposition to muscular exertion. These feelings, however, soon subside, and the individual returns to his usual state without experiencing the languor or depression which is so universally the consequence of intoxication from spirituous liquors.

DEUTOXIDE OF NITROGEN.—This gas is best obtained by the action of nitric acid, of specific gravity 1.2 on metallic copper.* The gas derived from this source was discovered by Dr. Priestley, who called it *nitrous air*. The terms *nitrous gas* and *nitric oxide* are frequently applied to it; the *deutoxide of nitrogen*, as indicative of its nature, is the most suitable name. It is a colourless gas, does not redden the blue vegetable colours; very few inflammable substances

* Many other metals are oxidized by nitric acid, with the disengagement of a similar compound; but none, mercury excepted, yields so pure a gas as copper.

can burn in it; it is quite inseparable, exciting a strong spasm of the glottis, as soon as an attempt is made to inhale it. The experiment, however, is a dangerous one; for if the gas reached the lungs, it would there mix with atmospheric air, and be converted into nitrous acid vapours, which are highly irritating and corrosive. (See *Elements of Chemical Philosophy*, by Sir H. Davy.)

CHAPTER XXVI.

CARBON.

Q. WHAT is the origin of carbon?

A. Pure carbon is known only in the diamond; but it may be procured in the state of charcoal by burning a piece of wood closely covered with sand, in a crucible, &c.

Obs.—Charcoal may be procured from other sources. When the volatile matters are driven off from coal, as in the process for making coal gas, a peculiar kind of charcoal, called *coke*, remains in the retort. Most animal and vegetable substances yield it when ignited in close vessels: *e. g.*, a very pure charcoal may be procured from starch or sugar; and from the oil of turpentine or spirit of wine, by passing their vapour through tubes heated to redness. When bones are made red hot in a covered crucible, a black mass remains, which consists of charcoal mixed with the earthy matters of the bone. This is called *ivory black* or animal charcoal.

Properties.—Charcoal is hard, brittle, and sonorous; very light and destitute of taste and

smell. It is a powerful antiseptic; has a great affinity for oxygen; is unalterable and indestructible by age; and, if air and moisture be excluded, it is not affected by the most intense heat.

Q. Is charcoal a simple or a compound substance?

A. Common charcoal is a compound substance—it is an oxide of carbon, or the woody fibre partially oxidized; it also contains hydrogen, and a portion of fixed alkaline salt and earth, but these are rather adventitious than essential ingredients.

Obs.—Messrs. Allen and Pepys lately determined by experiment that charcoal properly prepared contains no sensible quantity of hydrogen, but that it absorbs moisture if only exposed to the air for a few hours, which renders the result of analysis uncertain.

Q. What are the uses to which charcoal is applied?

A. Charcoal is a most important ingredient in the preparation of gunpowder; it is also employed in purifying rancid oils, for decomposing the sulphuric acid, and for many other purposes by the chemist and the manufacturer.* It is used by mathematical instrument makers and engravers, to polish brass and copper plates. Plates of horn and lantern leaves are polished with it; it is also much used by artists in tracing the outlines of drawings.

Q. What is carbon?

A. The base of common charcoal, divested of all impurities, is known by the name of carbon

* Casks charred in the inside are now used to preserve water in sea voyages; and such casks are found to preserve the water uncorrupted. See *Forsyth's Practical Treatise on Diet and Regimen*.

to chemists. Its most striking property is its capability of crystallization, in which state it is called *diamond*.

Q. What other properties has carbon?

A. It has the property of deoxidizing the oxides of metals and other combustible substances, and with this view it is often used in the arts. These purposes are effected by means of fire, the carbon uniting to the oxygen to form carbonic oxide, or carbonic acid; and the metal thus deprived of oxygen, is left in its pure state.

Q. Into what other combinations does carbon enter?

A. It is found in large proportions in bitumen, petroleum, and pitcoal;* it seems to be already formed also in vegetables; and enters into most animal and some mineral substances.

Obs.—Carbon is not only a component part, but forms nearly the whole of the solid basis of all vegetables, from the most delicate flower in the garden to the huge oak of the forest. It has been discovered that air which has been spoiled by the breathing of animals is peculiarly fitted for the vegetation of plants; a circumstance, doubtless, owing to its containing a larger portion of carbonic acid.

In the animal kingdom, carbon is a necessary part of sugar, of oils, &c.; it consequently enters into the composition of animal milk, and of animal oil and fat: it is also found in albumen, gelatine, fibrine, and in many of the animal secretions.—See *Carbonic acid*.

Carbonic oxide gas.—Priestley discovered this gas by igniting chalk in a gun barrel: and he afterwards obtained it in greater quantity from chalk and iron filings. He supposed it to

* On the formation of coal, consult *Williams's History of the Mineral Kingdom*; and *Parkinson's Organic Remains*.

be a mixture of hydrogen and carbonic acid gases. Its real nature was pointed out by Cruickshank,* and nearly at the same time by Clement and Desormes.†

Carbonic oxide gas is colourless and insipid. It does not in any way affect the blue colour of vegetables, nor does it combine, like carbonic acid, with lime or any of the pure alkalies. Lime water does not absorb it, neither does it affect its transparency. It is inflammable; it cannot support respiration; it acts injuriously on the system; for, if diluted with air, and taken into the lungs, it very soon occasions headache and other unpleasant feelings; and when breathed pure, it almost instantly causes profound coma. A mixture of carbonic oxide and oxygen gas may be made to explode by flame, by a red hot solid body, or by the electric spark.

Exp.—If carbonic oxide and oxygen gases be mixed together in the proportion of 100 measures of the former, and rather more than 50 of the latter, and the mixture be inflamed in Volta's eudiometer by electricity, so as to collect the product of the combustion, the whole of the carbonic oxide, with the 50 measures of oxygen, will disappear, and 100 measures of carbonic acid gas will occupy their place.

Obs.—The specific gravity of carbonic oxide is 0.9721. Dr. Henry has ascertained that when a succession of electric sparks is passed through carbonic acid confined over mercury, a portion of that gas is converted into carbonic oxide and oxygen. When a mixture of hydrogen and carbonic acid gases is electrified, a portion of the latter yields one-half of its oxygen to the former, water is generated, and carbonic oxide produced.

* *Nicholson's Journ.* 4to. ed. vol. v.

† *Ann. de Chimie*, vol. xxxix.

CHAPTER XXVII.

SULPHUR.

As a mineral production, sulphur occurs in some parts of the earth, particularly in the neighbourhood of volcanoes, as in Italy and Sicily. It is commonly found in a massive state; but is sometimes met with crystallized in the form of an oblique rhombic octahedron. It exists more abundantly in combination with several metals, as silver, copper, antimony, lead, and iron. It is procured in large quantity by exposing the common iron pyrites to a red heat in close vessels.

Sulphur is a brittle solid, of a greenish yellow colour, emits a peculiar odour when rubbed, and has little taste. It is a non-conductor of electricity, and is excited negatively by friction. Its specific gravity is 1.99. At the temperature of 190° F. it begins to liquefy; at 20° F. it is in a state of perfect fusion, and if then cast into cylindrical moulds, forms the common roll sulphur of commerce. When the heat is raised to 300° or 350° F. it becomes viscid and acquires a reddish brown colour; and if poured at this temperature into water, it becomes a ductile mass, and may be used for taking the impression of seals.*

Fused sulphur, on cooling, has a tendency to

* If sulphur be kept melted in an open vessel, it at length becomes thick; and it has the peculiar property of becoming thinner as it cools, till it is nearly as thin as water. This is an exception to the general law, by which caloric causes the particles of bodies to recede from each other.

crystallize. A crystalline arrangement is perceptible in the centre of the common roll sulphur; and by good management regular crystals may be obtained.

Obs.—Sulphur has been discovered in cresses, horseradish, and several other vegetables. It is also evolved from animal substances, during their putrefaction, in combination with hydrogen. The change which silver undergoes when immersed in an egg, shows the presence of sulphuretted hydrogen.

Sulphur is very volatile; it begins to rise slowly in vapour even before it is completely fused. At 550° or 600° F. it volatilizes rapidly, and condenses again unchanged in close vessels. It is by this process that common sulphur is purified; and if the sublimation be conducted slowly, the sulphur collects in the receiver in the form of detached crystalline grains called *flowers of silver*—a state, however, in which it is not quite pure; for the oxygen of the air within the apparatus combines with a portion of sulphur during the process, and forms sulphurous acid, which may be removed by washing the flower repeatedly with water.

Sulphur is insoluble in water, but unites with it under favourable circumstances, forming the white *hydrate of sulphur*, termed *lac sulphuris*. It dissolves readily in boiling oil of turpentine. It is also soluble in alcohol, if both substances are brought together in the form of vapour. The sulphur is precipitated from the solution by the addition of water. Like charcoal, sulphur retains a portion of hydrogen so obstinately that it cannot be wholly freed from it either by fusion or sublimation. Heated in the open air at 300° F. or a little higher, it kindles spontaneously, and burns with a faint blue light. In oxygen gas it

combustion is far more vivid; the flame is much longer, and of a bluish white colour. Sulphurous acid, in both cases, is the product;—no sulphuric acid is formed even in oxygen gas unless moisture be present.

Compound of Sulphur and Oxygen.—There are four compounds of sulphur and oxygen, all of which have acid properties,—the composition of which is as follows :—

	Sulphur.	Oxygen.	S.	Ox.
Hyposulphurous acid,	16	8	1	1
Sulphurous acid,	16	16	1	2
Sulphuric acid,	16	24	1	3
Hyposulphuric acid,	32	40	2	5

Obs.—Sulphur will also combine with the alkalis: *c. g.* with potass, soda, and with ammonia,—compounds which possess several curious and interesting properties. The alkaline and earthy sulphurets are hard substances of a brown colour resembling the liver of animals; they absorb water from the atmosphere, and then emit a foetid odour similar to that of putrid eggs. They decompose water, and by that process they become partially converted to alkaline or earthy sulphates.

. Sulphur may be combined artificially with most of the metals, and with some earths; but many of the metallic sulphurets are found native in great abundance.—See *Acids*.

CHAPTER XXVIII.

PHOSPHORUS.

PHOSPHORUS is a peculiar substance, chiefly of animal origin, discovered about the year 1669

by Brandt, an alchemist of Hamburg. It was formerly obtained by a tedious and disgusting process from urine, &c.; but it is now generally procured by the decomposition of the phosphoric acid which is found in animal bones. The object of both processes is to bring phosphoric acid in contact with charcoal at a strong red heat. When bones are used they are first ignited in an open fire till they become quite white, so as to destroy all the animal matter they contain, and to oxidize the carbon proceeding from its decomposition. The calcined bones, of which phosphate of lime constitutes nearly four-fifths, should be reduced to a fine powder, and digested for a day or two with half their weight of concentrated sulphuric acid, so much water being added to the mixture as to give it the consistence of a thin paste. The phosphate of lime is decomposed by the sulphuric acid, and two new salts are generated—the insoluble neutral sulphate, and the soluble bi-phosphate of lime. On the addition of boiling water the bi-phosphate is dissolved, and may be separated by filtration from the sulphate of lime. The solution is then evaporated to the thickness of syrup, mixed with one-fourth of its weight of charcoal in powder, and is heated in an earthen retort well luted with clay. The beak of the retort is put into water, in which the phosphorus, as it passes over in the form of vapour, is collected. When first obtained, it is frequently of a reddish brown colour, owing to the presence of the phosphuret of carbon, which is generally formed during the process. It may be purified by being put into hot water, and pressed, while liquid, through chamois leather; or the purification may be rendered still more complete by a second distillation.

Pure phosphorus is transparent and almost colourless. It is so soft that it may be cut with a knife, and the cut surface has a waxy lustre. It fuses at 180° F., and at 550° F. it sublimes. It is exceedingly inflammable. Exposed to the air, at common temperatures, it undergoes a slow combustion; it emits a white vapour of a peculiar alliaceous smell, appears distinctly luminous in the dark, and is gradually consumed. On this account phosphorus should always be kept under water.

Exp.—The disappearance of oxygen which accompanies the above changes is shewn by putting a stick of phosphorus in a jar full of air, inverted over water. The volume of the gas gradually diminishes, and if the temperature of the air be at 60° F. the whole of the oxygen will be withdrawn in the course of twelve or twenty-four hours. The residue is nitrogen, containing about one-fortieth of its bulk of the vapour of phosphorus.

It is remarkable that the slow combustion of phosphorus does not take place in pure oxygen unless its temperature be about 80° F.; but if the oxygen is rarefied by diminished pressure, or diluted with nitrogen, hydrogen, or carbonic acid, then the oxidation occurs at 60° F. A very slight degree of pressure is sufficient to inflame phosphorus. Gentle pressure between the fingers, friction, or a temperature not much above its point of fusion, kindles it readily. It burns rapidly even in the air, emitting a splendid white light and causing an intense heat. Its combustion is far more rapid in oxygen gas, and the light proportionably more vivid.

Use of Phosphorus.—Phosphorus is used in forming phosphoric acid, in various chemical experiments, and in making phosphoric match bottles. These bottles may be prepared by mixing one part of flour of sulphur with eight of

CHAPTER XXIX.

BORON.—SELENIUM.—CHLORINE.—IODINE, &c.

THE existence of boron was discovered by Sir Humphrey Davy, in 1807, by exposing boracic acid to the action of a powerful galvanic battery; but a sufficient quantity of it was not obtained to enable him to determine its properties. It was procured in greater quantities by Gay-Lussac and Thenard, in 1808, by heating boracic acid with potassium. The boracic acid is, by this means, deprived of its oxygen, and boron is set free.

Obs.—Boron is a dark olive-coloured substance, which has neither taste nor smell, and is a non-conductor of electricity. Boracic acid is the only known compound of boron and oxygen.

SELENIUM.—Selenium for the most part occurs, in combination with sulphur, in some kinds of iron pyrites. It has hitherto been found in very small quantity. It was discovered, in 1818, by Berzelius, in the sulphur obtained by sublimation from the iron pyrites of Fahlun*.

At common temperatures, selenium is a brittle, opaque, solid body, without taste or smell. It has a metallic lustre, and the aspect of lead,

* In the manufactory of sulphuric acid, at which this sulphur was employed, it was observed that a reddish-coloured matter always collected at the bottom of the leaden chamber; and on burning this substance, Berzelius perceived a strong and peculiar odour, similar to that of decayed horse-raddish, which induced him to submit it to a careful examination, and thus led to the discovery of selenium.

when in mass; but is of a deep red colour when reduced to powder. Its specific gravity is between 4.8 and 4.32. At 212° F. it softens, and is then so tenacious that it may be drawn out into fine transparent threads, which appear red by transmitted light. It is insoluble in water. It suffers no change from mere exposure to the atmosphere; but if heated in the open air, it combines readily with oxygen, and two compounds, the oxide and the acid of selenium, are generated.

CHLORINE.—Scheele, while investigating the nature of manganese, in 1770, discovered this substance, and described it under the name of *dephlogisticated marine acid*. The French chemists called it *oxygenized muriatic acid*, a term afterwards contracted to *oxymuriatic acid*, from an opinion proposed by Berthollet, that it is a compound of muriatic acid and oxygen. (See *Oxymuriatic Acid*.)

Obs.—Muriatic or hydrochloric acid gas was discovered by Priestly, in 1772. Chlorine unites with oxygen in four different proportions; and for the knowledge of chlorine and carbon, chemists are indebted to the ingenuity of Mr. Faraday; called the perchloride of carbon, &c.

There are two definite compounds of chlorine and phosphorus, the nature of which was first satisfactorily explained by Sir H. Davy. (See his *Elem. of Chem.* p. 290.)

Chlorocarbonic acid was discovered by Dr. John Davy in 1812, who described it in the Philosophical Transactions for that year under the name of phosgene gas.

IODINE.—Iodine was discovered by M. Cour-

tois, a manufacturer of saltpetre, in 1812, at Paris. In preparing carbonate of soda from the ashes of sea-weeds, he observed that the residual liquor corroded metallic vessels powerfully; and in investigating the cause of the corrosion, he noticed that sulphuric acid threw down a dark coloured matter, which was converted by the application of heat into a beautiful violet vapour. Struck with its appearance, he presented some of the substance to M. Clement, by whom it was recognised as a new body, and who, in 1812, described some of its leading properties in the Royal Institute of France. Its real nature was soon after determined by Gay-Lussac and Sir Humphrey Davy, each of whom proved that it was a simple non-metallic substance, exceedingly analogous to chlorine*.

At common temperatures, iodine is a soft friable opaque solid, of a bluish-black colour, and metallic lustre. It occurs usually in crystalline scales, having the appearance of mica-ceous iron ore; but it sometimes crystallizes in large rhomboidal plates, the primitive form of which is an octahedron. According to Gay-Lussac, its specific gravity is 4.948; but Dr. Thompson found it only 3.0844. It fuses at 225° F., and enters into ebullition at 347° F.; but when moisture is present, it sublimes rapidly, even below the degree of boiling water, and suffers a gradual dissipation at low temperatures. Its vapour is of an exceedingly rich violet colour, a character to which it owes the name of iodine.

Iodine is a non-conductor of electricity, and, like oxygen and chlorine, is a negative electric.

* The original papers on this subject are in the *Annales de Chimie*, vols. lxxviii., xc., and xci., and in the *Phil. Trans.* for 1814 and 1815.

It has a very acrid taste, and its odour is nearly similar to that of iodine, when much diluted with air. It acts energetically on the animal system as an irritant poison, but in small doses it is advantageously employed in medicine. It is sparingly soluble in water, requiring about 7000 times its weight of that liquid for solution. It possesses an extensive range of affinity. It destroys vegetable colours, though in a much less degree than chlorine. It is freely dissolved in alcohol and ether, and the solution has a deep reddish-brown colour. It manifests little disposition to combine with metallic oxides; but it has a strong attraction for the pure metals, and for most of the simple non-metallic substances. These combinations are termed *Iodides* or *Iodurets*. It is not inflammable; but under favourable circumstances may, like chlorine, be made to unite with oxygen. The violet hue of the vapour is, for many purposes, a sufficiently sure indication of its presence.

BROMINE.—This new substance, supposed to be simple, has been recently discovered in seawater by M. Balard, of Montpellier. The name first applied to it by the discoverer is *muride*.

At common temperatures bromine is a liquid, of a blackish-red colour when viewed in mass and by reflected light, but appears hyacinth-red when a thin stratum is interposed between the light and the observer. Its odour, which somewhat resembles that of chlorine, is very disagreeable, and its taste powerful. It acts with energy on organic matters, such as wood or cork, and corrodes the animal texture; but if applied to the skin for a short time only, it communicates a

yellow stain, which is less intense than that produced by iodine, and soon disappears. It is highly destructive to animals, one drop of it placed on the beak of a bird having proved fatal. Its specific gravity is about 3. It is a non-conductor of electricity—the voltaic pile does not decompose: it is soluble in water, in alcohol, and particularly in ether. It does not redden litmus paper, but bleaches it rapidly like chlorine; and it likewise discharges the blue colour from a solution of indigo.

Obs.—On mixing the vapour of bromine with hydriodic acid, sulphuretted hydrogen, or phosphuretted hydrogen gases, decomposition follows, and a colourless gas, possessed of acid properties, called hydrobromic acid, is generated.

The bromates are analogous to the chlorates and iodates.

* * M. Balard has ascertained that bromine exists in marine plants which grow on the shores of the Mediterranean sea, and has procured it in appreciable quantity from the ashes of the sea-weeds that furnish iodine. He has likewise detected its presence in the ashes of some animals, especially in those of the *Jarthina violacea*, one of the testaceous molluscas.

CHAPTER XXX.

AMMONIACAL GAS.*

FOR the purposes of experiment, this gas is most conveniently formed by applying a gentle

* Spirit of hartshorn has long been familiar to chemists; but the existence of ammonia, as a gas, was first noticed by Dr. Priestley, and described by him under the name *alkaline air*. It is sometimes called the *volatile alkali*, though the terms ammonia and ammoniacal gas are now most commonly employed.

heat to the concentrated solution of ammonia, contained in a glass vessel. It soon boils, and a large quantity of pure ammonia is set free.

Ammoniacal gas is colourless; has a strong pungent taste, and acts powerfully on the eyes and nose. It is quite irrespirable in a pure form, but when diluted with air, it may with safety be inhaled. It extinguishes burning bodies, and the gas is not inflamed by coming in contact with them. Ammonia, however, is inflammable in a low degree; for when a lighted candle is immersed in it, the flame is somewhat enlarged, and tinged of a pale yellow colour at the moment of being extinguished; and a small jet of the gas will burn in an atmosphere of oxygen. A mixture of ammoniacal and oxygen gases detonates by the electric spark; water is formed, and nitrogen remains. A little nitric acid is generated at the same time, except when less oxygen is employed than is sufficient for combining with all the hydrogen of the ammonia. (See *Dr. Henry in Philos. Trans. for 1809.*)

At the common temperature of 50° F., and under a pressure equal to 6.5 atmospheres, ammoniacal gas becomes a transparent colourless fluid.

Ammonia has all the properties of an alkali in a very remarkable degree. It has an acid taste, and gives a brown colour to turmeric paper; though the yellow colour soon re-appears on exposure to the air. It combines also with acids, and completely neutralizes their properties.

Obs.—Hydrogen and nitrogen gases, of which ammoniacal gas is composed, do not unite directly; chemists, therefore, have no synthetic proof of the constitution of ammonia. Though analytically its composition has been accurately determined.

By passing electric sparks through ammoniacal gas, it is resolved into its elements. The same effect is produced by conducting ammonia through porcelain tubes heated to redness. (See *Exp.*)

CHAPTER XXXI.

COMPOUNDS OF HYDROGEN AND CARBON.

THERE are two distinct compounds of hydrogen and carbon, with which chemists for some time past have been acquainted—namely, the carburetted hydrogen and olefiant gas; but Mr. Faraday has discovered two new substances of a similar nature, and demonstrated the existence of others, though hitherto he has been unable to obtain them in an insulated form. According to Dr. Thompson, naptha and naphthaline are likewise pure carburets of hydrogen.

LIGHT CARBURETTED HYDROGEN.—This gas is sometimes called *heavy inflammable air*, *the inflammable air of Marpes*, *hydro-carburet*, and *proto-carburet of hydrogen*. It is abundantly formed in stagnant pools during the spontaneous decomposition of dead vegetable matter; and it may readily be procured by stirring the mud at the bottom of them, and collecting the gas, as it escapes, in an inverted glass vessel. This gas is tasteless, and nearly inodorous. It does not change the colour of litmus or turmeric paper. It extinguishes all burning bodies, consequently it is unable to support the respiration of animals.

It is highly inflammable, and when a jet of it is set on fire, it burns with a yellow flame, and with a much stronger light than is occasioned by hydrogen gas. With atmospheric air or oxygen gas, in due proportions, it forms a mixture which detonates powerfully with the electric spark, or in coming in contact with flame. The sole products of the explosion are water and carbonic acid.

••• Mr. Dalton first ascertained the real nature of light carburetted hydrogen; and it has since been particularly examined by Dr. Thompson, Sir H. Davy, and Dr. Henry.

OLEFIANT GAS.—This gas is sometimes called *bi-carburetted* or *per-carburetted hydrogen*, and *hydroguret of carbon*; but the name olefiant gas given to it by the Dutch chemists, who discovered it in 1796, is that by which it is best known, from the property it possesses of forming an oily liquid with chlorine. It is prepared by mixing in a capacious retort six measures of strong alcohol with sixteen of concentrated sulphuric acid, and heating the mixture as soon as it is made by means of an Argand lamp. The acid soon acts upon the alcohol, effervescence ensues, and olefiant gas passes over. The chemical changes which take place are of a complicated nature, and the products numerous. In the process, the gas is derived solely from the alcohol; and its production is owing to the strong affinity of sulphuric acid for water.

Olefiant gas is a tasteless, colourless, elastic fluid, and when pure with scarcely any odour. It extinguishes flame; is unable to support the respiration of animals, and is set on fire when a lighted candle is presented to it, burning slowly with the

emission of a dense white light. It forms a mixture, with a proper quantity of oxygen gas, which may be kindled by flame or the electric spark, and which explodes with great violence. Chlorine acts powerfully on olefiant gas; and in the proportion of two measures of the former to one of the latter, they take fire on the approach of flame, and burn rapidly with formation of muriatic acid gas, and deposition of a large quantity of charcoal. But if the gases, after being mixed, are allowed to remain at rest, a very different action follows; for the chlorine, instead of decomposing the olefiant gas, enters into direct combination with it, and a yellow liquid-like oil is generated, called *chloric ether*; though the term *hydrocarburet* of *chlorine*, as indicative of its composition, is more appropriate.

Obs.—Hydrocarburet of chlorine was discovered by the associated Dutch chemists; but Dr. Thompson (*Memoirs of the Wernerian Society*, vol. i.) was the first who ascertained it to be a compound of olefiant gas and chlorine; and its nature has since been more fully explained by the researches of MM. Robiquet and Colin. (See *Ann. de Chimie et de Phil.* vol. i. and ii.)

. For the new carburets of hydrogen discovered by Dr. Faraday, see *Annals of Philosophy, New Series*, vol. vi.; also *Turner's Elem. of Chem.* p. 285, *et seq.*

COAL AND OIL GAS.—For the nature of the inflammable gases derived from the destructive distillation of coal and oil first discovered by Dr. Henry, see *Nicholson's Journal* for 1805; *Philosophical Transactions* for 1808 and 1821, and *Edinburgh Philosophical Journal* for 1825.

Obs.—The chief constituents of coal and oil gas were found by Dr. Henry to be light carburetted hydrogen and olefiant gas,

besides which, they contain an inflammable vapour, free hydrogen, carbonic acid, carbonic oxide, and nitrogen gases. Mr. Faraday has still further proved that there exists in oil gas, and by inference in coal gas also, the vapour of several definite compounds of carbon and hydrogen, the presence of which for the purposes of illumination, is exceedingly important.

* * The preparation of coal and oil gas is a process of considerable delicacy, being performed by heating coal to redness in iron retorts. As regards the economy of the two gases, it may be observed that the illuminating power of oil gas, of specific gravity 0.900, is about double that of coal gas of 0.600. In coal districts, however, oil gas is fully three times the price of coal gas; in such places, therefore, the latter is considerably cheaper. (*See the Authorities above quoted.*)

CHAPTER XXXII.

COMPOUNDS OF HYDROGEN AND SULPHUR.

Sulphuretted Hydrogen.—This gas is formed, in a pure state, by heating sulphuret of antimony in a retort, or any convenient glass flask, with four or five times its weight of strong muriatic acid. It may also be procured by the action of sulphuric or muriatic acid, diluted with three or four parts of water, or the protosulphuret of iron, which may be formed either by igniting common iron pyrites (the deuto-sulphuret of iron) by which one atom of sulphur is expelled; or by exposing to a low red heat a mixture of two parts of iron filings, and rather more than one of sulphur; placing the materials in a common earthen or iron crucible, protected, during the process, as much as possible from the air.

Obs.—Sulphuretted hydrogen gas is colourless, and is distinguished from all other gaseous substances by its offensive taste and smell, which is similar to that of rotten eggs, or the water of sulphurous springs. It is very injurious to animal life. It extinguishes all burning bodies; but the gas takes fire when a lighted candle is immersed in it, and burns with a pale blue flame. It has decided acid properties; for it reddens litmus paper, and forms salts with alkalies; hence it is sometimes called *hydrosulphuric acid*; and its salts are called *hydrosulphurets* or *hydrosulphites*; all of which are decomposed by muriatic or sulphuric acid, and sulphuretted hydrogen is disengaged with effervescence. Water and sulphurous acid are the products of its combustion, and sulphur is deposited.

The affinity of sulphuretted hydrogen for metallic substances, renders it a chemical agent of considerable importance. It tarnishes gold and silver, and forms with them metallic sulphurets. White paint, owing to the lead it contains, is blackened by it; and the salts of nearly all the common metals are decomposed by its action. The most delicate chemical test of its presence is white paint (carbonate of lead) mixed with water, and spread upon a piece of white paper. By this means so minute a quantity of sulphuret of hydrogen may be detected, that one measure of the gas mixed with 20,000 times its volume of air, hydrogen, or carburetted hydrogen, gives a brown stain to the whitened surface. *Henry.*

Obs.—An atmosphere charged with sulphuretted hydrogen may, in the space of a few minutes, be purified by means of chlorine. This gas is composed of sixteen parts of sulphur and one of hydrogen. Its specific gravity, compared with that of hydrogen, is sixteen to one. One hundred cubical inches of it weigh thirty-six grains.

Bi-sulphuretted Hydrogen.—This compound, though discovered by Scheele, was first particu-

larly described by Berthollet. It is easily made by boiling equal parts of recently slacked lime and flowers of sulphur with five or six of water, when a deep orange-yellow solution is formed, which contains a hydrosulphuret of lime with excess of sulphur. On pouring the liquid into strong muriatic acid, a copious deposition of sulphur ensues; and the greater part of the sulphuretted hydrogen, instead of escaping with effervescence, is retained by the sulphur. After some minutes, a yellowish semi-fluid matter like oil collects at the bottom of the vessel, which is bi-sulphuretted hydrogen.

Obs.—The salts of bi-sulphuretted hydrogen may be prepared by digesting sulphur in solutions of the alkaline or earthy hydro-sulphurets. They are also generated when alkalies or alkaline earths are boiled with sulphur and water; though in this case another salt is formed at the same time.

Exp.—On boiling lime and sulphur, as in the preceding process, the only mode by which sulphuretted hydrogen can be formed at all is by the decomposition of water; but as no oxygen escapes during the ebullition, it is manifest that the elements of that liquid must have combined with separate portions of sulphur, and have formed two distinct acids. One, in all probability, hydrosulphurous acid; the other, sulphuretted hydrogen.

. The salts of the bi-sulphuretted hydrogen absorb oxygen from the air, and pass gradually into hyposulphites; and a similar change is rapidly effected by the action of sulphurous acid.

CHAPTER XXXIII.

HYDROGEN AND SELENIUM—HYDRO-SELENIC ACID.

LIKE sulphur, selenium forms a gaseous compound with hydrogen, which has distinct acid properties, and is termed *seleniuretted hydrogen*, or *hydro-selenic acid*. It may be procured by heating the seleniuret of iron in muriatic acid. It is also disengaged when muriatic acid is added to a solution of hydro-seleniate.

Hydro-selenic acid is colourless. Its smell is, at first, similar to that of sulphuretted hydrogen; but it afterwards irritates the lining membrane of the nose powerfully and excites catarrhal symptoms, and for some hours destroys the sense of smelling. It is absorbed freely by water, forming a colourless solution, which reddens litmus paper, and gives a brown stain to the skin. It is soon decomposed by exposure to the atmosphere; in consequence of the oxygen of the air uniting with the hydrogen of the hydro-selenic acid, and selenium, a precipitate in the form of a red powder, subsides. By hydro-selenic acid, all the salts of the common metals are decomposed.

CHAPTER XXXIV,

PERPHOSPHURETTED HYDROGEN.

THIS compound of hydrogen and phosphorus was discovered, in 1783, by M. Gengembre, since

which it has been particularly examined by Mr. Dalton and Dr. Thompson. It may be prepared several ways.

1. By heating phosphorus in a strong solution of pure potass.

2. By heating a mixture made of small pieces of phosphorus and recently slacked lime, to which a sufficient quantity of water is added to give it the consistence of a thick paste.

3. By the action of dilute muriatic acid, assisted by a moderate heat, on the phosphuret of lime.

In all of these processes three compounds of phosphorus are generated:

1. Phosphoric acid.

2. Hypophosphorous acid.

3. Perphosphuretted hydrogen;

all of which are produced by the decomposition of water and the combination of its elements, which separate portions of phosphorus. The gas should be generated at as slow a temperature as possible, or otherwise some free hydrogen is apt to pass over. Phosphuretted hydrogen has a bitter taste, and a peculiar smell resembling that of garlic. The solution does not redden litmus paper, nor does the gas itself possess acid properties.

Obs.—From the combustibility of this gas, it would be dangerous to put it in any quantity with air or oxygen in close vessels. For the same reason care is requisite in making the gas, to allow it to form very slowly at first, that the oxygen within the apparatus may be gradually consumed.

. The specific gravity of phosphuretted hydrogen, according to Dr. Thompson, is 0.9027; and one hundred cubic inches at 60° F., and when the barometer stands at thirty inches, weigh 27.5223 grains. Recently boiled water absorbs

about one-fiftieth of its volume, and acquires the peculiar odour of the gas.

Protophosphuretted Hydrogen.—This colourless gas, which has the following properties, was described by Sir H. Davy, in 1813. Its odour, though disagreeable, is less foetid than the preceding. Water absorbs about one-eighth of its volume. It does not take fire when mixed with air or oxygen at common temperatures, but the mixture detonates with the electric spark, or when heated to the temperature of 300° F. Admitted to chlorine gas it instantly inflames, emitting a white light; which it possesses in common with the perphosphuretted hydrogen. It is prepared by heating the solid hydrate of phosphorous acid in close vessels. (See Sir H. Davy's *Elem. of Chemistry*, p. 297.)

CHAPTER XXXV.

COMPOUNDS OF NITROGEN AND CARBON.

Bi-carburet of Nitrogen, or Cyanogen Gas.—Cyanogen gas was discovered by M. Gay-Lussac in 1815. It is formed by heating the cyanuret of mercury, carefully dried, in a small retort, by means of a spirit lamp. On the supposition of its being a compound of the oxide of mercury and prussic acid, it was formerly called *prussiate of mercury*; and is in reality composed of metallic mercury and cyanogen. On exposing it to a low red heat it is resolved into its

elements. The cyanogen passes over in the form of gas, and the metallic mercury sublimes. It is colourless, and has a pungent and very peculiar odour. It extinguishes burning bodies; but is inflammable, and burns with a beautiful and characteristic purple flame. It can support a strong heat without decomposition; and though a compound body, it has a remarkable tendency to unite with elementary bodies. Its affinity, on the contrary, for metallic oxides is comparatively feeble.

Obs.—All the compounds of cyanogen, which are not acid, are called *cyanurets* or *cyanides*.

HYDROCYANIC OR PRUSSIC ACID.—This acid was discovered by Scheele, in 1762. Berthollet ascertained afterwards that it contains carbon, nitrogen, and hydrogen; but the discovery of cyanogen enabled Gay-Lussac to procure it in a pure state, and thereby to determine its real nature.

Prussic acid may be prepared by heating the cyanuret of mercury in a glass retort with two-thirds of its weight of concentrated muriatic acid. Vauquelin proposes a method by which it may be procured more abundantly; which consists in filling a narrow tube, horizontally placed, with fragments of the cyanuret of mercury, and causing a current of sulphuretted hydrogen gas to pass slowly along it. The instant that gas comes in contact with the cyanuret, double decomposition ensues, and hydrocyanic acid and black sulphuret of mercury are generated. The progress of the sulphuretted hydrogen along the tube may be distinctly traced by the change of colour, and the experiment may be closed as

soon as the whole of the cyanuret has become black. All that now remains is to expel the hydrocyanic acid by a gentle heat, and collect it in a cool receiver. This is an easy, elegant, and productive process.

Pure hydrocyanic acid is a limpid colourless fluid, with a strong odour similar to that of peach blossoms. It excites, at first, a coolness of the tongue, which is soon followed by heat; but when diluted it has the flavour of bitter almonds. It is so exceedingly volatile that its vapour, during warm weather, may be collected over mercury. Its specific gravity at 45° F. is 0.7058. Its point of ebullition is 79° F., and at zero it congeals. It is so powerful a poison that a single drop of it placed on the tongue of a dog, causes death in the course of a very few seconds; and small animals confined in its vapour, are speedily destroyed.

From the powerful action of hydrocyanic acid on the animal economy, this substance, in a diluted form, is sometimes employed medicinally. The quantity of dilute hydrocyanic acid, however prepared, is very variable, owing to the volatility of the acid, and its tendency to spontaneous decomposition. On this account it should be made only in small quantities at a time, kept in well stopped bottles, and excluded from the light.

Hydrocyanic acid may be procured of any given strength by dissolving the cyanuret of mercury in water, and passing a current of sulphuretted hydrogen through the solution till the whole is decomposed. The excess of sulphuretted hydrogen is removed by agitation with carbonate of lead, and the hydrocyanic acid is after-

wards separated from the insoluble matter by filtration. At Apothecaries' Hall, the process adopted is to mix in a retort one part of the cyanuret of mercury, one part of muriatic acid of the specific gravity of 1.15, and six parts of water, and to distil the mixture. The produce has a density of 0.995. (Brande's *Manual of Chem.*, vol. i.)

CYANIC ACID.—This acid is characterised by the facility with which it is resolved by water into the carbonic acid and ammonia. This change is effected by merely boiling an aqueous solution of the cyanate of potass; and it takes place more rapidly when an attempt is made to decompose the cyanate by means of another acid. If the acid is diluted, the cyanic acid is instantly decomposed, and the carbonic acid escapes with effervescence. But, on the contrary, if a concentrated acid be employed, then the cyanic acid resists decomposition for a short time, and emits a strong odour of vinegar.

According to Wöhler, the cyanate of potass may be procured in large quantity by mixing the ferrocyanate of potass with an equal weight of the peroxide of manganese in fine powder, and exposing the mixture to a low red heat. The cyanogen of the ferrocyanic acid receives oxygen from the manganese, and is converted into cyanic acid, which unites with the potass. The ignited mass is then boiled in alcohol of eighty-six per cent.; and as the solution cools, the cyanate is deposited in small tubular crystals like the chlorate of potass.

The cyanic acid forms a soluble salt with barytes, but insoluble ones with the oxides of

lead, mercury and silver. If the cyanate of potass be quite pure, it gives a white precipitate with nitrate of silver, and the cyanate of silver thus formed dissolves without residue in dilute nitric acid.

The cyanic acid of M. Liebig, a powerfully detonating compound of mercury, was described in the Philosophical Transactions, for 1800, by Mr. E. Howard. It is prepared by dissolving one hundred grains of mercury in a measured ounce and a half of nitric acid of specific gravity 1.3, and adding, when the solution has become cold, two ounces, by measure, of alcohol, the density of which is 0.849. The mixture is then heated till a moderately brisk effervescence takes place, during which the fulminating compound is generated. A similar substance may be made by treating silver in the same manner.

Qbs.—Fulminating silver and mercury bear the heat of 212° or even 260° F. without detonating; but a higher temperature, or slight percussion between two hard bodies, causes them to explode with violence. The nature of these compounds was discovered in 1823, by M. Liebig (*Ann. de Ch. et de Ph.*, vol. xxiv.) who demonstrated that they are salts composed of a peculiar acid, which he termed *fulminic acid*, in combination with the oxide of mercury or of sulphur.

* * The cyanic acid has not yet been obtained in an insulated form; for while some acids do not decompose the cyanates, others act on the cyanic acid itself, and give rise to new products.

Chlorocyanic Acid.—The existence of this acid was first noticed by Berthollet, who called it *oxyprussic acid*, on the supposition of its containing prussic acid and oxygen; but its real composition having been determined by Gay-Lussac, he proposed the more appropriate term of chloro-

cyanic acid. When chlorine is conducted into an aqueous solution of hydrocyanic acid till the liquid acquires bleaching properties, and the excess of chlorine is then removed by agitation with mercury, two acids are obtained, one of which is the muriatic acid, and the other a compound of cyanogen and chlorine.

Obs.—This acid has not hitherto been procured in a separate state. When first formed, it is mixed with muriatic acid and water; and, on heating the solution, a gas is expelled which may be collected over mercury, and which, on examination, is found to be a mixture of chlorocyanic and carbonic acid.

Cyanogen and Iodine.—The cyanuret of iodine, discovered, in 1824, by M. Serullas, may be prepared by the following process:—

Ex.—Two parts of the cyanuret of mercury and one of iodine, quite dry, are intimately mixed in a glass mortar, and the mixture is introduced into a phial with a wide mouth. On applying heat, the violet vapours of the iodine appear; but as soon as the cyanuret of mercury begins to be decomposed, the vapour of iodine is succeeded by white fumes, which, if received in a cool glass receiver, condense upon its sides into flocks like cotton wool.

Obs.—When slowly condensed, the cyanuret of iodine occurs in very long and exceedingly slender needles, of a white colour. It has a very caustic taste and penetrating odour, and excites a flow of tears. It dissolves in water and alcohol, and forms solutions which do not redden litmus paper. When water is present, the sulphurous acid has a very powerful action on the cyanuret of iodine. On adding a few drops of this acid iodine is set free, and hydrocyanic acid is produced; but when more of the sulphurous acid is employed, the iodine disappears, and the solution is found to contain hydriodic acid. These changes are of course accompanied with the formation of sulphuric acid, and the decomposition of water.

Ferrocyanic Acid.—Within these few years past, the ferrocyanic acid has been under the judicious researches of Mr. Porret, Berzelius, and M. Robiquet. Mr. Porret recommends two methods for obtaining it, by one of which it is procured in crystals, and by the other in a state of solution. The first process consists in dissolving fifty-eight grains of crystallized tartaric acid in alcohol, and mixing the liquid with fifty grains of the ferrocyanate of potass, dissolved in the smallest possible quantity of hot water. The bi-tartrate of potass is precipitated, and the clear solution, on being allowed to evaporate spontaneously, gradually deposits ferrocyanic acid in the form of small cubic crystals of a yellow colour. (See *Note, &c.* p. 133.)

CHAPTER XXXVI.

SUBSTANCES WHICH, IN RELATION TO OXYGEN,
CONTAIN AN EXCESS OF HYDROGEN.

1. OILS.

— Fixed.
— Volatile.
— Camphor.

2. RESINS.

— Amber
— Balsams.
— Gum Resins.
— Caoutchouc.
— Wax.

3. ALCOHOL.

ETHER.

— Sulphuric Ether.
— Nitrous Ether.
— Acetic Ether.
— Muriatic Ether.
— Hydriodic Ether.

4. BITUMINOUS SUBSTANCES.

— Naptha. — Retinasphaltum.
— Petroleum. — Pit Coal.
— Asphaltum. — Glance Coal.
— Mineral Pitch.

OILS.—Q. How are oils characterised?

A. By a peculiar unctuous feel, by their inflammability, and insolubility in water.

Q. How are oils divided?

A. They are divided into the fixed and volatile, the former of which being comparatively fixed in the fire, and therefore give a permanently greasy stain to paper; while the latter, owing to their volatility, produce a stain which disappears by gentle heat.

Q. In the seeds of what plants are the fixed oils usually contained?

A. In the seeds of the almond, linseed, rapeseed, and poppy seed: but olive oil is extracted from the pulp which surrounds the stone.

Q. How are these oils procured?

A. They are procured by bruising the seed, and subjecting the pulpy matter to pressure in an hempen bag, a gentle heat being generally employed at the same time to render the oil more limpid.

Obs.—Fixed oils, the palm oil excepted, are fluid at common temperatures; are nearly inodorous, and have little taste. They are lighter than water, are commonly of a yellow colour, but may be rendered nearly or quite colourless by the action of animal charcoal. They undergo considerable change by exposure to the air. They do not unite with water, though they may be permanently suspended in that fluid by means of sugar or mucilage, so as to form an emulsion. For the most part they are sparingly soluble in alcohol and ether. Strong sulphuric acid thickens the fixed oils, and forms with them a tenacious matter like soap: and they are also rendered thick and viscid by the action of chlorine. Concentrated nitric acid acts upon them with great energy, giving rise in some instances to the production of flame. Fixed oils unite with the common metallic oxides, and are readily attacked by alkalis.

Volatile Oils.—Volatile oils may be obtained by distillation, water being put into the still along with the plant, in order to prevent the latter from being burnt. It is to the presence of a volatile or essential oil that aromatic plants owe their flavour.

Obs.—Essential oils have a penetrating odour and acid taste, which are often pleasant when sufficiently diluted. They unite with the fixed oils in every proportion, and are sometimes adulterated with them.

Volatile oils burn in the open air with a clear light, and the sole products of the combustion are water and carbonic acid. They do not readily unite with metallic oxides, and are attacked with difficulty even by the alkalies.* They dissolve sulphur in large quantity, forming a deep brown coloured liquid, called balsam of sulphur. The solution is best made by boiling flour of sulphur in spirit of turpentine. Phosphorus may likewise be dissolved by the same menstruum.

* * The most interesting of the essential oils are those of

Turpentine	Anise
Caraway	Lavender
Cloves	Cinnamon
Peppermint	Citron
Nutmeg	Chamomile :

Of these the most important is the first, which is much employed in the preparation of varnishes, and for some medical and chemical purposes.

CAMPHOR.—*Q.* How is camphor obtained ?

A. Camphor, which in several respects, is closely allied to the essential oils, exists ready formed in the *laurus camphora* of Japan, from the trunk, root and branches of which it is obtained by sublimation.

Q. What are the properties of camphor ?

A. It is inflammable ; has a bitterish, aromatic, pungent taste, accompanied with a sense of coolness. It is unctuous and brittle ; but it possesses a degree of toughness, which prevents it from being easily pulverised. It is exceedingly volatile, being gradually dissipated in

* The substance called Starkey's soap, is made by triturating oil of turpentine with an alkali.

vapour if kept in open vessels. At 288° F. it enters into fusion, and boils at 400° F. Its specific gravity is 0.988.

Obs.—Camphor is insoluble in water; but when triturated with sugar, and then mixed with that fluid, a portion is dissolved sufficient for communicating its flavour. It is dissolved freely by alcohol, and is thrown down by the addition of water. It is likewise soluble in fixed and volatile oils, and in strong acetic acid. Sulphuric acid decomposes camphor, converting it into a substance like artificial tannin. With the nitric it yields sulphuric acid.

RESINS.—Q. What are resins?

A. Resins are the inspissated juices of plants, and commonly occur either pure or in combination with an essential oil. They are solid at common temperatures, brittle, inodorous, and useful. They are generally of a yellow colour, and some transparent.

Obs.—Resins are dissolved by alcohol, ether and the essential oils, and the alcoholic and ethereal solutions are precipitated by water, a fluid in which they are quite insoluble; their best solvent is pure potassa and soda; and they are also soluble in the alkaline carbonates, by the aid of heat. Concentrated sulphuric acid dissolves resins; but the acid and the resin mutually decompose each other, with disengagement of sulphurous acid, and deposition of charcoal.

Q. What are the uses of resin?

A. The uses of resin are various. Melted with wax and oil, resins constitute ointments and plasters; with oil or alcohol, they form different kinds of oil and spirit varnish. Sealing wax is composed of lac, Venice turpentine, and common resin. The composition is coloured black, by means of lamp-black, or red, by cinnabar and red lead. Lamp-black is the soot of imperfectly burned resin.

Q. Which are the most important resins?

A. Of the different resins, the most important are common resin, copal, lac, sandarach, mastic, elemi, and dragon's blood. The first is procured by heating turpentine, which consists of oil of turpentine and resin, so as to expel the volatile oil.

Obs.—The common turpentine, obtained by incisions made in the trunk of the Scotch fir-tree (*pinus sylvestris*), for the above purpose; but the other kinds of turpentine, such as the Venice turpentine, from the larch (*pinus larix*); the Canadian turpentine from the *pinus balsamea*, or the Strasburgh turpentine from the *pinus pricca*, yield resin by a similar treatment.

Q. Where is *amber* found?

A. Amber is found chiefly on the coasts of Pomerania, Livonia, Prussia, and Denmark, occurring sometimes in beds of bituminous woods.

Obs.—Amber is unquestionably of vegetable origin, and has the general properties of a resin; but it differs from resinous substances in yielding succinic acid, when heated in close vessels.

Q. Describe the balsams, and the manner in which they are procured?

A. The balsams are native compounds of resin and benzoic acid. They issue from incisions made in the trees, which contain them, in the same manner as turpentine from the fir.

Obs.—Some of the balsams, as storax and benzoin, are solid; while others, as the balsams of Tolu and Peru, &c., are fluid.

Q. What are the *gum resins*?

A. The gum resins are the concrete juices of certain plants, and consist of resin, essential oil, gum, and extractive vegetable matter. The

two former principles are dissolved by alcohol, and the two latter in water.

Obs.—Under the class of gum resins are comprehended several valuable medicines; *e. g.*, aloes, ammoniacum, asafoetida, euphorbium, galbanum, gamboge, myrrh, scammony, and guaiacum.

Q. What is *caoutchouc*?

A. *Caoutchouc*, commonly called elastic gum or Indian rubber, is the concrete juice of the *hevea caoutchouc* and *jatropha elastica*, natives of South America, and of the *figus Indica*, and *artocarpus integrifolia*, which grow in the East Indies.

Q. What are its properties?

A. It is a soft yielding solid, of a whitish colour when not blackened by smoke, possessing considerable tenacity, and is particularly remarkable for its elasticity. It is inflammable, and burns with a white light. When cautiously heated, it fuses without decomposition. It is insoluble in water and alcohol; but it dissolves, though with some difficulty, in pure ether. It is sparingly dissolved by the alkalies, but its elasticity is destroyed by their action. It is decomposed by the nitric and sulphuric acids; the former causing a deposition of charcoal, and the latter a formation of oxalic acid. It is soluble in the essential oils, in petroleum and in cajeput oil, and may be procured by evaporation from the two latter, without loss of its elasticity.

Wax.—Wax partakes of the nature of fixed oil; it is an abundant vegetable production, entering into the composition of the pollen of flowers, covering the envelope of the plumb and

other fruit, especially the berries of the *myrica cerifera*, and in many instances forming a kind of varnish to the surface of leaves. From this circumstance it was long supposed that the wax is solely of vegetable origin, and that the wax of the honey-comb is derived from the flowers only; but, from the observations of Huber, it appears that it must likewise be regarded as an animal product, as he found bees to deposit wax, though fed on nothing but sugar.

Obs.—Common wax is always more or less coloured, and has a distinct peculiar odour, of both which it may be deprived by exposure in thin slices to air, light, or more speedily by the action of chlorine. It is insoluble in water, and is only sparingly dissolved in boiling alcohol or ether. It is readily attacked by the fixed alkalis, being converted into a soap, which is soluble in hot water. It unites by the aid of heat in every proportion with the fixed and volatile oils, and with resin. With different quantities of oil it constitutes the liniment, ointment and cerate of the Pharmacopœia. Its specific gravity is 0.96. At about 150° F., it enters into fusion, and boils at a high temperature. It is employed also for making candles, as it burns with a clear white light.

. According to John's observations, wax consists of two different principles, one of which is soluble, and the other insoluble in alcohol. To the former he has given the name of *cerin*, and to the latter *myricin*.

ALCOHOL.—Alcohol is the inebriating ingredient of all vinous and spirituous liquors. It is the product of the vinous fermentation. It is a colourless elastic fluid, of a penetrating odour, and burning taste. It is highly volatile, boiling, when its density is 0.820, at the temperature of 176° F. According to Gay-Lussac, the specific gravity of its vapour is 1.613. Like volatile liquids in general, it produces a considerable

degree of cold during its evaporation. Of all fluids, it is the only one which has not hitherto been congealed. It is highly inflammable, and burns with a lambent yellowish blue flame. It unites with water in every proportion.

Obs.—Of the salifiable bases, alcohol alone can dissolve potassa, soda, lithia, ammonia, and the vegetable alkalis. All the salts which are either insoluble, or sparingly soluble in water, are insoluble in alcohol. The efflorescent salts are, likewise, for the most part insoluble in this menstruum; but, on the contrary, it is capable of dissolving all the deliquescent salts, except the carbonate of potass. Many of the vegetable principles, as sugar, manna, camphor, resins, balsams, and the essential oils, are soluble in alcohol.

Alcohol is inferred to consist of

Carbon	-	-	12	2 atoms	-	-	52.17
Oxygen	-	-	8	1 atom	-	-	34.79
Hydrogen	-	-	3	3 atoms	-	-	13.04

23.

100,000

These numbers are in such proportion, that alcohol may be regarded as a compound of fourteen parts, or one atom of olefiant gas, and nine parts or one atom of water.

ETHER.—The word ether was formerly employed to designate the volatile inflammable liquid formed by heating a mixture of alcohol and sulphuric acid; but the same term has since been extended to several other compounds, produced by the action of acids on alcohol, and which from their volatility, and inflammability, were supposed to be identical or nearly so with sulphuric ether. It appears, however, from the researches of several chemists, that ethers, though analogous in the leading properties, frequently

differ both in composition and in the mode of formation.—*Mem. d'Arcueil*, vol. i. ii.

Sulphuric Ether is a colourless fluid, of a hot pungent taste, and fragrant odour. Its specific gravity in its purest form, is about 0.700, or according to Loveby, 0.632; but that of the shops is 0.74.

Obs.—Ether combines with alcohol in every proportion, but is sparingly soluble in water. It is highly inflammable, burning with a blue flame, and formation of water and carbonic acid.

Nitrous Ether.—This compound is prepared by distilling a mixture of concentrated nitric acid in an equal weight of alcohol; but as the reaction is apt to be exceedingly violent, the process requires to be conducted with extreme care.

Obs.—The nitrous ether agrees with sulphuric in its leading properties; but is still more volatile.

Acetic Ether.—This is analogous in composition to the preceding, and is formed by distilling acetic acid with an equal weight of alcohol.

Obs.—According to Thenard, the acetic is the only vegetable ether which forms ether by being heated alone with alcohol.

Muriatic Ether.—This compound, prepared by distilling a mixture of concentrated muriatic acid and pure alcohol, was supposed by Thenard to be analogous in composition to nitrous ether. It appears, however, by MM. Robiquet and Colin, that it consists of muriatic acid and the elements of elephant gas, consequently quite free from oxygen.

Hydriodic Ether, first prepared by Gay-

Lussac, appears to be similar in composition to muriatic ether.

BITUMINOUS SUBSTANCES.—Under this head are included several inflammable substances, which though of a vegetable origin, are found in the earth. These may be conveniently arranged under the two heads of Bitumen and Pit-coal.

The First, or bitumen, comprehends naphtha, petroleum, mineral tar, mineral pitch, asphaltum, and retinasphaltum, of which the three first mentioned are liquid, and the others solid.

The Second, or pit-coal, comprises brown coal, the different varieties of common or black coal, and *glance* coal. (See *Thompson's An. Phy.* vol. xv.)

CHAPTER XXXVII.

**SUBSTANCES WHOSE OXYGEN AND HYDROGEN
ARE IN EXACT PROPORTIONS FOR FORMING
WATER.**

SUGAR.—Sugar is a vegetable product, existing abundantly in several ripe fruits, though few of them contain it in sufficient quantity for being collected. The juice of the American maple tree is so powerfully saccharine, that it may be applied to many useful purposes. In France and Germany, during the late war, sugar was prepared from the beet-root; and Proust extracted it in Spain from grapes. But that at

present used in Europe, is obtained from the sugar-cane (*Arunda saccharifera*), which contains it in greater quantity than any other plant.

Molasses.—The saccharine principle of treacle has been supposed to be different from crystallizable sugar; though probably it consists of common sugar, prevented from crystallizing by the presence of foreign substances, such as saline, acid, and other vegetable matters. The sugar procured from grapes, has the essential properties of common sugar; and that obtained from beet-root, appears identical with common sugar.

Honey.—According to Proust, honey contains two kinds of saccharine matter, one of which crystallizes readily, and is analogous to common sugar, while the other is uncrystallizable. It contains also mucilaginous colouring, and odoriferous matter, and probably a vegetable acid.

Manna.—This is the concrete juice of several species of ash, particularly the *Fraxinus ornus*. The sweetness of manna is owing, not to sugar, but to a distinct principle, called *mannite*, which differs from sugar, in not fermenting when mixed with water and yeast.

STARCH OR FECULA.—*Amidine*. Starch exists abundantly in the vegetable kingdom; and is one of the principal ingredients of most varieties of grain, of some roots, such as the potato, and the kernels of leguminous plants.

Obs.—The *Indian arrow-root*, prepared from the root of the *Maranta arundinacea*, has all the characters of pure starch. *Sago*, obtained from the pith of an East Indian palm tree (*Cycas circinalis*), and *tapioca*, from the root of the

Jatropha Manihot, are chemically the same substance. They both exist in the plants from which they are extracted in the form of starch; but as heat is employed in their preparation, the starch is more or less completely converted into *amidine-Salop*, when obtained from the *Orchis mascula*, consists almost entirely of the substance called *bassorin*, with a small quantity of gum and starch.

GUM.—This is a common proximate principle of vegetables, and is not confined to any particular part of plants. The purest variety of this substance is the gum Arabic, the concrete juice of the several species of the *mimosa* or *acacia*, natives of Africa and Arabia.

Obs.—Besides gum Arabic, there are a variety of well-marked gums, especially the gum tragacanth, the gum of the cherry-tree, and the mucilage from linseed. All these varieties, though distinguishable from one another by some peculiarity, have the common character of yielding the saccholactic by the action of nitric acid. (See *Dr. Bestock in Nicholson's Journal*, vol. xviii.)

. The substance called *vegetable jelly*, as derived from the currant, appears to be a mucilage of some other modification of gum combined with vegetable acid.

LIGNIN.—The *woody fibre*, or *lignin*, constitutes the fibrous structure of vegetable substances, and is most abundant in plants. The different kinds of wood contain about 96 per cent. of *lignin*. It is prepared by digesting the sawings of any kind of wood successively in alcohol, water, and dilute muriatic acid, until all the substances soluble in these menstrua are removed.

Obs.—When *lignin* is heated in close vessels, it yields a large quantity of impure acetic acid (pyroligneous acid) and charcoal if great purity remains in the retort. Digested in nitric acid, *lignin* is converted into the *oxalic*, *malic*, and *acetic acids*.

CHAPTER XXXVIII.

THE following substances, as far as hitherto known, do not belong to either of the preceding chapters.

COLOURING MATTER.—There exists in the colour of vegetable substances an infinite diversity of matter; but the prevailing tints are red, yellow, blue, and green, or a mixture of these colours. Nearly all kinds of vegetable colouring matter are decomposed by the agency of the sun's rays and a moist atmosphere, and they are all without exception destroyed by chlorine. Acids and alkalies commonly change the tint of vegetable colours, entering into combination with them to form compounds. Several of the metallic oxides, and especially alumina, and the oxides of iron and tin, form, with colouring matter, insoluble compounds, to which the name of lakes is applied. Lakes are commonly obtained by mixing alum or the muriate of the peroxide of tin with a coloured solution, and then by means of an alkali precipitating the oxide which unites with the colour at the moment of separation. On this property are founded many of the processes in dyeing and calico printing. On this subject the reader desirous of obtaining the particular details, may consult *Berthollet's Elements de la Teinture*; *Dr. Bancroft's Treatise on permanent Colours*; a *Paper by Mr. Henry, in the Manchester Memoirs*, vol. iii.; *Thenard and Roard's Essay*, in vol. 74 of the *Annales de Chimie*.

TANNIN.—This substance exists abundantly in the excrescences of several species of the oak, called gall-nuts; in the bark of most trees; in some inspissated juices, such as kino and catechu; in the leaves of the tea-plant, sumach, whortleberry, and in all astringent plants, being the chief cause of the astringency of vegetable matter. It is frequently associated with gallic acid, as in gall-nuts, most kinds of bark, and in tea; but in kino, catechu and cinchona bark, no gallic acid is present.

Obs.—The most characteristic property of tannin is its action on a salt of iron and a solution of gentianine. With the peroxide of iron, or better still with the protoxide and peroxide mixed, tannin forms a black-coloured compound, which, with the gallate of iron, constitutes the basis of writing ink and the black dyes. Artificial tannin, an interesting substance, was discovered upwards of twenty years ago by Mr. Hatchet, who gave a full account of it in the Philosophical Transactions for 1805 and 1806. The best method of preparing it is by the action of nitric acid on charcoal. It may also be generated by the action of pure nitric acid, both in animal or vegetable charcoal, and on pit-coal, asphaltum, jet, indigo, common resin, and several other resinous substances. It is also prepared by heating common resin, elemi, assafoetida, camphor, balsams, &c., first with sulphuric acid and then with alcohol.

GLUTEN, YEAST, VEGETABLE ALBUMEN.—Gluten is procured by a similar process to that for preparing starch. It is present in most kinds of grain, such as wheat, barley, rye, oats, peas and beans; but the first contains it in the largest proportion; and this is the reason that wheaten bread is more nutritious than that made with most other kinds of flour.

Obs.—M. Taddey, an Italian chemist, has succeeded in obtaining two distinct principles from gluten, to one of which he

has given the name of *gliadine*, from $\gamma\lambda\alpha$, *gluten*, and to the other that of *zymome*, ζυμη, a ferment.—*Ann. of Phil.* vol. xv.

Gliadine is a brittle, slightly transparent substance, of a yellow colour, and a sweetish balsam taste. Its smell, in the cold, is like that of honey-comb; but when heated, it emits an odour similar to that of boiled apples.

Zymome is a tough hard substance, but does not possess the viscosity of gluten. It is insoluble in water and alcohol; but is dissolved in vinegar and the mineral acids by the aid of heat; and forms a soap with pure potassa.

YEAST.—This substance is always generated during the various fermentation of vegetable juices and decoctions, rising to the surface in the form of a frothy, flocculent, somewhat viscid matter, the nature and composition of which are unknown. Its most remarkable property is that of exciting fermentation,

VEGETABLE ALBUMEN.—There are vegetables which contain a substance coagulable by heat, and which is very analogous to animal albumen or curd. It was detected in the bitter almond by Vogel; in the sweet almond by M. Boullay, and probably exists in most of the emulsive seeds.—*Annals of Philos.* vol. xii. p. 39.

ASPARAGIN.—A principle discovered by MM. Vauquelin and Robiquet in the juice of the asparagus, from which it is deposited in crystals by evaporation.—*Ann. de Chimie*, vol. lvii.

BASSORIN.—First noticed in gum Bassora by Vauquelin

CAFFEIN.—This principle was discovered in coffee by M. Robiquet in the year 1821, and was soon after obtained from the same source by MM. Pelletier and Caventou.

CATHARTIN.—A name applied by MM. Lassaigne and Feneuille to the active principle of senna.—*An. de Ch. et de Phil.* vol. xvi.

FUNGIN.—A name given by M. Branconnot to the fleshy substance of the mushroom, and is procured in a pure state by digestion in hot water, to which a little alkali is added. It is nutritious in a high degree, and in composition is very analogous to animal substances.

SUBERIN.—A name applied by M. Chevreul to the cellular tissue of the common cork, the outer bark of the cork oak (*quercus ruber*). Suberin differs from all the other vegetable principles by yielding the suberic when heated by nitric acid.

ULMIN, discovered by Klaproth, is a substance which exudes spontaneously from the elm, oak, chesnut, and other trees; and according to Berzelius is a constituent of most kinds of bark.

LUPULIN is the name applied by Dr. Ives, to the active principle of the hop, but which has not yet been obtained in a state of purity.

INULIN is the white starch-like powder spontaneously deposited from a decoction of the roots of the *Inula helenium*, or *elecampane*.

MEDULLIN, the name given by John to the

pith of the sun flower; though its existence as an independent principle is rather dubious. The term *pollenin* has been applied by the same chemist to the pollen of tulips.

PIPERIN.—A name applied to a white crystalline substance extracted from black-pepper.—*Pelletier, in An. de Ch. et de Phil.* vol. xvi.

OLIVILE.—A peculiar substance; when the gum of the olive oil is dissolved in alcohol, and the solution is allowed to evaporate spontaneously, apparently different from the other proximate principles hitherto examined, is deposited in flattened needles, or as a brilliant amylaceous powder. To this M. Pelletier has given the name of *olivile*.—*An. of Phil.* vol. xii.

SARCOCOLL.—The concrete juice of the *penæa sarcocallo*, a plant which grows in the northern parts of Africa.

RHUBARBIN.—The name employed by Pfaß to designate the principle in which the purgative property of the rhubarb resides. The active principle of this plant is regarded by M. Naniel of Milan as a vegetable alkali; but he has not produced any proof of its alkaline nature.—*Jour. of Science*, vol. xvii. p. 172.

COLOCYNTIN.—The name employed by Vauquelin to a bitter resinous matter extracted from colocynth, and to which he ascribes the properties of this substance.—*Journal of Science*, vol. xxiii. p. 400.

BITTER PRINCIPLE.—A name formerly ap-

plied to a substance supposed to be common to bitter plants, and to be the cause of their peculiar taste.

Obs.—The recent discoveries in vegetable chemistry have not shown that the bitter principle can no longer be regarded as an uniform and unvarying principle. For instance, the bitterness of the *nux vomica* is owing to *strychnine*, that of opium to *morphine*, and that of cinchona bark to cinchonine and quinine. The cause of the bitter taste in the root of the squill is different from that of the hop or of gentian. The term bitter principle, therefore, ought to be abandoned.

EXTRACTIVE MATTER.—If applied to one determinate principle supposed to be the same in plants, this expression is no less vague than the foregoing. It is indeed true that most plants yield to water a substance which differs from gum, sugar, or any proximate principles of vegetables, which therefore constitutes a part of what is called an *extract* in pharmacy, and which for want of a more precise term, may be expressed by the name of *extractive*. It should, however, be remembered that this matter is always mixed with other proximate principles, and that there is no proof whatever of its being identical in different plants.

Ex.—A solution of saffron in hot water, said to afford extractive matter by evaporation, contains the colouring matter of the plant, with all the other vegetable principles of saffron, which happen to be soluble in the menstruum employed.

Q. What are the terminations of spontaneous changes of vegetable matter?

A. The spontaneous changes of vegetable matter sometimes terminates in the formation of sugar, at another time in that of alcohol, at a third in that of acetic acid, and at a fourth in the total dissolution of the substance—hence the division of the four above distinct kinds of fermentative processes.

Q. What are the substances known to be subject to the process of fermentation?

A. The only substance known to be subject to the fermentative process is starch.

Ex.—When gelatinous starch, or amidine, is kept in a moist state for a considerable length of time, a change gradually ensues, and a quantity of sugar, equal to about half the weight of the starch, is generated. The germination of seeds, as exemplified in the malting of barley, is likewise an instance of the saccharine fermentation; and the ripening of fruits has also been regarded as an example of it; especially since some fruits, such as the pear and apple, if gathered before their maturity, become sweeter by keeping. The opinion, however, of Proust is, that the process of ripening appears to consist in the conversion, not of starch, but of acid into sugar.

Q. What are the conditions required for establishing the vinous fermentation?

A. These conditions are four in number, namely, the presence of sugar, water, yeast, and a certain temperature.

Q. What is the best mode of studying this process?

A. The best mode of studying this process, so as to observe the phenomena, and determine the nature of the change, is to place five parts of sugar, with about twenty of water, in a glass flask furnished with a bent tube, the extremity

of which opens under an inverted jar full of water and mercury; and after adding a little yeast, to expose the mixture to a temperature of about 60° or 70° F. In a short time bubbles of gas begin to collect in the vicinity of the yeast, and the liquid is soon put into a brisk motion, in consequence of the formation and distension of a large quantity of gaseous matter; the solution becomes turbid, its temperature rises, and froth collects upon its surface. After continuing for a few days, the evolution of gas begins to abate, and at length ceases altogether; the impurities gradually subside, and leave the liquor clear and transparent.

Obs.—The only appreciable changes found to have taken place during the above process, are the disappearance of the sugar and the formation of alcohol, which remains in the flask, and of carbonic acid gas, which is collected in the pneumatic apparatus.

Q. What is meant by the acetous fermentation?

A. The acetous fermentation consists in the conversion of alcohol, &c., into acetic acid, *e. g.* When any fluid has undergone the vinous fermentation, or even pure alcohol, diluted with water, is mixed with yeast, and exposed in a warm place to the open air, an intestine movement speedily commences, heat is developed, the fluid becomes turbid from the deposition of a peculiar filamentous matter, oxygen is absorbed from the atmosphere, and carbonic acid is disengaged. After a certain time, these changes cease spontaneously; the liquor becomes clear, and instead of alcohol, it is now found to contain acetic acid.

Obs.—The vinous may easily terminate in the acetous fermentation. The latter is conducted on a large scale for yielding the common vinegar; which, thus obtained, always holds in solution a large quantity of mucilaginous and other vegetable matters, the presence of which renders it liable to several ulterior changes.

Q. What is implied by the putrefactive fermentation?

A. By the putrefactive fermentation is implied a process unattended with the phenomena which accompanies the saccharine, the vinous, or the acetous fermentations, but during which the acetous matter is completely decomposed.

Q. What are the conditions requisite to enable the putrefactive process to go on?

A. Moisture, air, and a certain temperature.

Obs.—The air cannot be regarded as absolutely necessary, since putrefaction is found to be produced by the concurrence of the two other conditions only; though doubtless the process is materially promoted by free exposure to the influence of the atmosphere.

Q. Are all proximate principles equally liable to this kind of dissolution?

A. No: substances in which charcoal and hydrogen prevail, such as the oils, resins, and alcohol, do not undergo the putrefactive fermentation; nor do acids, which contain a considerable excess of oxygen, manifest any tendency to submit to this change.

Q. What are the substances most disposed to utrefy?

A. Those substances alone are disposed to putrefy, the oxygen and hydrogen of which are in proportion to form water; and such in particular as contain nitrogen; among which, however, a singular difference prevails.

Ex.—Caffein evinces no tendency to spontaneous decomposition, while gluten, which certainly must contain a less proportional quantity, putrefies with great facility.

Obs.—Those substances, the texture of which is most loose and soft, being, *cæteris paribus*, the most liable to spontaneous decomposition.

CHAPTER XL.

ANIMAL CHEMISTRY.

THIS branch of chemical science embraces all distinct compounds derived from the bodies of animals, and these are called *proximate animal principles*.

Q. How are these substances distinguished from inorganic matter?

A. They are distinguished from inorganic matter by the characters which belong to the latter, namely, inorganic chemistry includes the doctrine of affinity, and the laws of combination, together with the chemical history of all the elementary principles hitherto discovered, and of those compound bodies which are not the product of organization.

Q. What are the circumstances which serve to distinguish *proximate animal principles* from vegetable matter?

A. The principles which serve to distinguish the former from the latter are, the presence of nitrogen, their strong tendency to putrefy, and the highly offensive products to which their spontaneous decomposition gives rise.

Obs.—It should nevertheless be borne in mind, that nitrogen is likewise a constituent of many vegetable substances: though few of these, the *vegeto-animal* principles excepted, are prone to submit to the process of putrefactive fermentation, it is equally remarkable, that there are compounds of animal origin, such as chlorestine and the oils, which do not contain nitrogen as one of their elements, still they are not disposed to putrefy.

Q. What are the essential constituents of animal compounds?

A. The essential constituents of animal compounds are carbon, hydrogen, oxygen, and nitrogen. Some of them also contain phosphorus, iron, sulphur, and earthy and saline matters in small quantity.

Obs.—All the proximate animal principles contain a large quantity of carbon, and their hydrogen is in such proportion as to convert all their oxygen into water, and their nitrogen into ammonia.

FIBRIN.—**Q.** What is fibrin?

A. Fibrin is one of those animal substances, which is neither acid nor oleaginous. It enters largely into the composition of the blood, and is the basis of the muscles: it may consequently be regarded as one of the most abundant of the animal principles.

Q. How is fibrin procured?

A. Fibrin may be easily procured by stirring recently drawn blood with a stick during its coagulation, and then washing the adhering fibres with water until they are perfectly white. It may also be obtained by removing the soluble parts from lean beef, cut into small slices, by digestion in several successive portions of water.

Q. What are the properties of fibrin?

A. Fibrin is solid, white, and inodorous. It is somewhat elastic when moist, but on drying it becomes hard, brittle, and semi-transparent. In a moist warm situation it readily putrefies. It is insoluble in water at common temperatures, and is dissolved in very minute quantity by the continued action of boiling water. Alcohol, of density 0.81, converts it into a fatty adipocircous substance, which is soluble in alcohol and ether, but is precipitated by water, &c.

Obs.—The action of acids on fibrin has been particularly described by Berzelius. (See *Med. Chirug. Trans.* vol. iii. p. 201. *et seq.*)

ALBUMEN.—Q. Describe the nature and properties of albumen?

A. Like fibrin, albumen is neither an acid nor an oleaginous substance. It enters largely into the composition of animal fluids and solids. Dissolved in water it forms an essential constituent of the serum of the blood, the liquor of the serous cavities, and the fluid of dropsy; and, in a solid state, it is contained in several of the textures of the body, such as the cellular membrane, the skin, glands, and vessels. Hence it appears that albumen exists under two forms, liquid and solid.

Q. How is liquid albumen best procured?

A. Liquid albumen is best procured from the white of eggs, which consists solely of this principle, united with water and free soda, and mixed with a small quantity of saline matter.

Obs.—Liquid albumen is coagulated by heat, alcohol, and the stronger acids. It is precipitated by several re-agents, especially by metallic salts. It coagulates without appearing to undergo any decomposition, &c.

GELATINE.—Q. Where does gelatine exist?

A. Gelatine exists abundantly in many of the solid parts of the animal body, especially in the skin, cartilages, tendons, membranes, and bones.

Obs.—According to Berzelius, gelatine is not contained in any of the healthy animal fluids; and Dr. Bostock, with respect to the blood, has demonstrated the accuracy of this statement.

Q. How is it distinguished from other animal principles?

A. Gelatine is distinguished from all other animal principles by its ready solubility in boiling water, and by the solution forming a bulky semi-transparent, tremulous jelly as it cools. Its tendency to gelatinize is such, that one part of gelatine, dissolved in 100 parts of water, becomes solid in cooling.

Obs.—This jelly is a hydrate of gelatine, and contains so much water, that it readily liquefies when warmed. On expelling the water by a gentle heat, a brittle mass is left, which retains its solubility in hot water, and may be preserved for any length of time without change. Jelly, on the contrary, soon becomes acid by keeping, and then putrefies.

*. The common gelatine of commerce is the well-known cement called *glue*, which is prepared by boiling cuttings of parchment, or the skins, ears, and hoofs of animals, and evaporating the solution. Isinglass, the purest variety of gelatine, is prepared from the sounds of fish of the genus *acipenser*, especially from the sturgeon. The animal jelly of the confectioners is made from the feet of calves, the tendinous and ligamentous parts of which yield a large quantity of gelatine.

Gelatine is insoluble in alcohol, but is dissolved readily by most of the diluted acids,

which form an excellent solvent for it; also by the liquid alkalies, and the solution is not precipitated by the acids. The best precipitate for it is tannin.

UREA.—*Q.* How is pure urea procured?

A. Pure urea is procured by evaporating fresh urine to the consistence of a syrup, and then gradually adding to it, when quite cold, pure concentrated nitric acid, till the whole becomes a dark-coloured crystallized mass, which is to be slightly washed with cold water, and then dried by pressure, between two folds of bibulous paper. To the nitrate of urea procured in this manner, a pretty strong solution of the carbonate of potassa or soda is added, until the acid is neutralized, and the solution is afterwards concentrated by evaporation, and set aside that the nitre may separate in crystals. The residual liquid, which is an impure solution of urea, is made up into a thin paste with animal charcoal, and is allowed to remain in that state for a few hours. The paste is then mixed with cold water, which takes up the urea, while the colouring matter is retained by the charcoal; and the colourless solution is evaporated to dryness at a low temperature. The residue is then boiled in pure alcohol, by which the urea is dissolved, and from which, on cooling, it is deposited in crystals (*Proust*).

Obs.—Urea is decomposed by the pure fixed alkalies and alkaline earths, especially by the aid of heat, carbonate of ammonia being the chief product. (For an account of its properties, see Proust in *Medico-Chirug. Trans.* vol. viii. p. 529.)

SUGAR OF MILK.—Sugar of milk is the saccharine principle of the milk obtained from whey, by evaporating that liquid to the consistence of syrup, and allowing it to cool. It is afterwards purified by means of albumen and a second crystallization. Like starch, it is convertible into real sugar by being boiled in water, and acidulated with sulphuric acid. It has a sweet taste, though less so than the sugar-cane. It is not susceptible of the vinous fermentation. It yields the saccholactic acid, which distinguishes the saccharine principle of milk from every other species of sugar. It contains no nitrogen, and, according to Gay-Lussac and Thenard, is very analagous in the proportion of its principles to common sugar.

SUGAR OF DIABETES.—In the disease called diabetes mellitus, the urine contains a peculiar saccharine matter, which, when properly purified, appears identical, both in properties and composition, to vegetable sugar, approaching nearer to the sugar of grapes than to that of the cane. Dr. Proust discovered in it a minute proportion of nitrogen; though it is probable this gas originated in some animal matter derived from the urine. It is obtained by evaporating in an irregular crystalline mass by evaporating diabetic urine to the consistence of syrup, and keeping it in a warm place for several days. By repeated crystallization it is rendered quite pure. (*Proust.*)

CHAPTER XLII.

ANIMAL ACIDS.

SEVERAL acids are met with in animal bodies, such as the sulphuric, muriatic, phosphoric, acetic, &c., which belong equally to the mineral or vegetable kingdom, which have been described in another place. Under this head are included only such acids as are supposed to be peculiar to animal bodies.

1. *Uric or Lithic Acid*.—A common constituent of urinary and gouty concretions, and is always present in healthy urine, combined with ammonia or some other alkali.

Obs.—The urine of birds of prey, such as the eagle; and of the *boa-constrictor*, and other serpents, consists almost solely of urate of ammonia, from which pure uric acid may be procured by a very simple process. *Pyro-uric* acid is generated by exposing uric acid to heat in a retort, in which also the carbonate and hydrocyanate of ammonia are formed. (See *Dr. Henry*, and *MM. Chevalier and Lassaigue*, in *Ann. of Phil.* vol. xvi.)

2. *Purpuric Acid*.—A compound first recognised as a distinct acid by Dr. Proust, and described by him in the *Philosophical Transactions* for 1818. It is prepared by digesting pure uric acid from the urine of the *boa-constrictor*, in dilute nitric acid, when the former is dissolved with effervescence.

3. *Rosacic Acid*.—A name given by Dr. Proust to a peculiar acid, supposed to exist in the red

matter, commonly called by medical practitioners, the *lateritious sediment*, deposited from the urine in some stages of fever.

4. *Formic Acid*.—A distinct compound, extracted from ants.

5. *Lactic Acid*.—This acid, although described by Berzelius, and found by him in sour milk and in many animal fluids, has never been demonstrated in a satisfactory manner. Berzelius himself now admits it to be acetic acid disguised by animal matter—an opinion confirmed by Trede-
mann and Gmelin, in their experimental Essay on Digestion.

Amniotic Acid.—A weak acid, discovered by Burneva and Vauquelin, in the liquor of the amnios of the cow.

. Several other acids, as the stearic, oleic, margaric, &c. might be mentioned here; but which will, from being so closely allied to the fatty principles to which they are derived, be more conveniently alluded to in the following section.

ANIMAL OILS AND FATS.

1. *Train Oil*, is obtained by means of heat from the blubber of the whale, and is employed extensively in making oil gas, and for burning in common lamps.

2. *Spermaceti Oil*.—This is obtained from an oily substance lodged in a bony cavity in the head of the *Physeter macrocephalus*, or spermaceti whale.

3. *Animal Oil of Dippel*.—A limpid volatile oil, entirely different from those above-mentioned, and is a product of the destructive distillation of animal matter, especially of albumen.

ous acid, gelatinous substances, &c. It is now no longer employed in medicine.

4. *Hogs' Lard and Suet*.—The most common kinds of fat, which differ from each other chiefly in the degree of consistency.

Obs.—Both these kinds of fat, as well as train and spermaceti oil, consist almost entirely of stearine and elaine, and when converted into soap, undergo the same change as the fixed oils, yielding margaric and oleic acids, and the mild principle of oils called *glycerine*.

Stearine is the chief ingredient of suet, butter, and lard, and is the cause of their solidity; whereas oils contain a greater proportional quantity of elaine, and are consequently fluid. These principals may be separated from each other by exposing fixed oil to a low temperature, and pressing it, when congealed, between two folds of bibulous paper. The stearine is thus obtained in a separate form; and by pressing the bibulous paper under water, an oily matter is procured, which is elaine in a state of purity. This principle is peculiarly fitted for greasing the wheels of watches, or other delicate machinery, as it does not thicken or become rancid by exposure to the air, and requires a cold of about 20° F. for congelation.

Butyrine.—Butter differs from the common animal fats in containing a peculiar oleaginous matter which is quite fluid at 70° F., and to which M. Chevreul has applied the name of Butyrine. When converted into soap, it yields, in addition to the usual products, three volatile odoriferous compounds, namely, the butyric, caproic, and capric acids.

Phocæine is a peculiar fatty substance contained in the porpoise (*Delphinium phocæna*), mixed with elaine.

Hircine is contained in the fat of the goat and sheep.

Spermaceti.—This inflammable substance, prepared from the spermaceti whale as above-mentioned, commonly occurs in crystalline plates of a white colour and silvery lustre.

Adipocere.—When a piece of fresh muscle is exposed for some time to the action of water, or is kept in moist earth, the fibrin entirely disappears, and a fatty matter, called adipocere, remains, which has some resemblance to spermaceti.

Obs.—It was formerly thought that the fibrin was really converted into adipocire; but Gay-Lussac (*An. de Ch. et de Ph.*, vol. iv.) and Chevreul maintain that this substance proceeds entirely from the fat originally present in the muscle, and that the fibrin is merely destroyed by putrefaction. Dr. Thompson, however, maintains, that the conversion of fibrin into fat does not occur in some instances, and has related a remarkable case in proof of this opinion (See *Ann. Phil.* vol. xii. p. 41.) According to M. Chevreul, the adipocere is not a pure fatty principle, but a species of soap, consisting chiefly of margaric, and, in combination with ammonia, generated during the decomposition of the fibrin.

Chlorestine.—A name applied by Chevreul to the crystalline matter which constitutes the basis of most of the biliary concretions formed in the human subject. It has lately been detected in the bile of man, and of several of the liver animals, as the ox, dog, pig, and bear. This interesting discovery was made about the same time by Chevreul in Paris, and by Treddeman and

Gmelin in Heidelberg. M. Lassaigne has likewise found it in the biliary calculus of a pig.—(*An. de Ch. et de Ph.* vol. xxxi.)

Ambergris.—A substance found floating on the surface of the sea near the coasts of India, Africa, and Brazil, supposed to be a concretion formed in the stomach of the spermaceti whale. It has usually been considered as a resinous principle; but its chief constituent is a substance very analogous to chlorestine, and to which MM. Pelletier and Caventou have given the name of *ambreine*.

As ambergris has not been found in any whales but such as are dead or sick, its production is generally supposed to be owing to disease, though it has been affirmed by some to be the cause of the morbid affection. It is found in various sizes, generally in small fragments, but sometimes so large as to weigh near two hundred pounds. Its specific gravity ranges from 780 to 926. If good, it adheres like wax to the edge of the knife with which it is scraped, retains the impression of the teeth and nails, and emits a fat odoriferous liquid on being penetrated with a hot liquid. It is generally brittle; but on rubbing it with the nail, it becomes smooth like hard soap. Its colour is either white, black, ash-coloured, yellow, or blackish; or, it is variegated, namely, grey with black specks, or grey with yellow specks. Its smell is peculiar and not easily to be counterfeited. According to Bouillon La Grange, who has given the last analysis, 3820 parts of ambergris consist of adipocere 2016 parts, a resinous substance 1167, benzoic acid 425, and coal 212.

An alcoholic solution of ambergris, added in minute quantity of lavender water, tooth powder,

hair powder, wash balls, &c., communicates its peculiar fragrance. Its high price in London frequently causes it to be adulterated.

Obs.—By digestion in nitric acid, *ambreine* is converted into a peculiar acid called the ambreic acid.—(*An. of Phil.* vol. xvi.) This acid is yellowish-white, has a peculiar smell, reddens vegetable blues, does not melt at 212° F. and evolves no ammonia when decomposed at higher temperatures. It is soluble in alcohol and ether; but slightly so in water. Ambreate of potash gives yellow precipitates with muriate of lime, muriate of barytes, sulphate of copper, sulphate of iron, nitrate of silver, acetate of lead, corrosive sublimate, and muriate of gold.—*Jour. de Pharmacie*, v. xlix.

SELECT CHEMICAL EXPERIMENTS.

WE have selected the following simple experiments, which may be made with perfect ease and safety, for the practice of the student, with a view to impress upon his mind an early acquaintance with chemical facts.

I. TO PRODUCE CHANGE OF TEMPERATURE.

1. *To produce a sensation of cold.*—Hold a small phial, in one hand, containing some pulverised muriate of ammonia. If a little water be now poured upon it, and the mixture blacken, a sensation of cold will be immediately felt.

2. If a small metallic cup be half filled with good ether, and placed within a large watch glass half filled with water, and both be placed under the receiver of an air-pump; when the air is exhausted, the ether will boil, and the water be frozen. When the pressure of the atmosphere is unmoved by the air-pump from the surface of the ether, its own latent caloric occasions its expansion, and, absorbing caloric from the water, it becomes converted into gas; and the water having lost its caloric of fluidity, becomes *ice*.*

3. *Expansion.*—Put a spoonful of ether into a moistened bladder, in the absence of a proper glass vessel, and tie the

* It was proposed, some time ago, by professor Leslie, the making of ice in quantities by taking off the pressure of the atmosphere from several receptacles for water placed underneath a collection of the receivers of an air-pump. Mr. Carey, in the Strand, exhibits an apparatus of this kind, which is capable of making six pounds of ice by one exhaustion of glasses.

neck of the bladder closely. If hot water be now poured upon it, the ether will expand, and the bladder become inflated.

4. *Freezing mixture.*—Let five drachms of the muriate of ammonia, and five drachms of nitre, both finely powdered, be dissolved in two ounces of water. If a thermometer be immersed in this solution, it will indicate that the temperature is reduced below 32° . If a thermometer tube, filled with water, be now suspended within it, the water will soon be effectually frozen.

5. *Again.*—Take a glass tube with a bulb in the form of a common thermometer; let it be filled with cold water, and suspended by a string. If the bulb now be frequently and continually moistened with pure sulphuric ether, the water will be presently, and as effectually frozen, as in the above experiment, even in summer.

Obs.—In consequence of the quantity of caloric that liquids require to convert them into vapour, all evaporation produces cold. An animal might be frozen to death in the midst of summer, by repeatedly sprinkling ether upon him. Its evaporation would shortly carry off the whole of his vital heat. Water thrown on hot bodies acts in the same way; it becomes, in an instant, converted into vapour, and thus deprives these bodies of a great portion of the caloric they contain. The most striking example of the production of cold by rarefaction, is given by Dr. Wolfe, in his account of the Fountain of Hiers, at the mines of Chemnetz, in Hungary. In this curious machine, of which he has given a plate, the air is compressed by a ponderous column of water, 260 feet high; it happens, therefore, that whenever the stop-cock is opened, this compressed air rushes out with great vehemence, becoming immediately much expanded. The consequence of this sudden rarefaction is, that

the moisture the air contained is not only precipitated, but congealed; a part of which falls down in a shower of snow, and the other part forms icicles which adhere to the nose of the cock.—*Philosoph. Trans.* vol. iii.

6. *To produce heat by the formation of a salt.*—Place a small thermometer in a glass vessel containing about an ounce of a solution of soda; if a different quantity of muriatic acid be added to saturate the soda, the mercury in the thermometer will expand; affording an instance of heat being produced by the formation of a salt.

7. *The expansion of volatile bodies by heat may also be shown by the following experiment.*—Put a little ether into a small retort, tie a bladder to the beak of it, and hold the retort over a lamp. The ether will quickly boil, and the gas which arises from it will soon occupy the bladder, and extend it to its full size. If the bladder be then held in water, the gas will be condensed by the loss of its heat, and the bladder will collapse.

Note.—It is necessary, to ensure the success of this experiment, that the bladder should be previously warmed to 80 or 90 degrees, to prevent the gas from being condensed in the first instance.

8. *Combination of a substance with caloric.*—Charge a small retort with strong muriatic acid, and insert its beak into a tubulated receiver containing a little water; then into this receiver insert two small thermometers, the one immersed in the water, the other suspended above it. By applying the heat of the lamp to the retort, muriatic acid gas will be abundantly disengaged; and if the thermometers be examined, that which is suspended in the gas will be found to have risen only a few degrees, while that which was immersed in the cold water has acquired a boiling heat.

Obs.—The nature of the combination of a substance with caloric was first placed in a clear

light by Dr. Black. He discovered that all matter is subject to the following law, viz., that "whenever a body changes its chemical state, it either combines with or separates from caloric."

9. Take a glass of cold water, on the surface of which pour a little sulphuric ether, and inflame it by a slip of lighted paper. The ether will burn for a considerable time, and produce a large volume of flame; but when it is extinguished the water will be found not to have increased in temperature.

Obs.—The object of this last experiment is to show that water is a bad conductor of caloric, and that when we wish to heat water, the heat ought not to be applied at its surface.

10. Let the bulb of a thermometer be dipped in melted rosin so as to coat the glass with it, and suffer it to cool completely. Apply the flame of a taper to the bulb, so as to melt the rosin; the mercury in the thermometer will not rise at the approach of the taper, but will actually be seen to contract as the rosin becomes liquid.

11. *To produce diversity of colours.*—Put about a scruple of the oxidized manganese and nitrate of potash, as below directed,* in a wine glass, and an equal quantity of the same compound in another glass. On one pour hot, and on the other cold water. The hot solution will exhibit a beautiful green colour; the cold one a deep purple.

12. If a small portion of mineral cameleon be put into several glasses, and water at different temperatures be poured on

* Take one part of the black oxide of manganese and three parts of the nitrate of potash, both reduced to powder; mix them, and throw them into a red-hot crucible, and continued there until no more oxygen be disengaged. The result will be a friable powder, called *mineral cameleon*, from its property of changing colour during its solution in water. If a small quantity of this powder be put into a glass of water, the solution is first *blue*; oxide of iron then separates, and by its *yellow* colour renders the fluid green; this subsiding, the blue re-appears; then, as the oxide of manganese absorbs oxygen from the atmosphere, it becomes reddish, brownish, and at last black. If hot water, as above, &c.

each, the contents of each glass will exhibit a different shade of colour.

Obs.—This experiment affords another instance of metals producing various colours, according to their different modes of treatment.

13. Diffuse a little newly prepared white prussiate of iron in two or three wine glasses, each containing some distilled water, and let the action of the air be excluded by covering the contents of each with a thin layer of oil. If these colourless liquids be now exposed to different degrees of cold, it will be seen that whenever the water in either of them freezes, the white precipitate will become blue.

14. Hammer an iron bar briskly upon an anvil: its temperature will be soon so increased, that a piece of phosphorus being laid upon it will become instantly inflamed.

Obs.—The object of this experiment is to show that caloric may be evolved merely by percussion; and that, when evolved, it is as active and energetic as though it had never been latent.—(For other experiments on these subjects, see *Atmospheric Air*, p. 12, and *Caloric*, p. 18.)

II. EXPERIMENTS WITH THE GASES.

1. *Carbonic Acid Gas.*—If about an ounce of marble, grossly pulverized, be put into an eight ounce phial, with about an equal quantity of water, and a little sulphuric acid be poured upon it, carbonic acid gas will be evolved. See p. 183.

Obs.—The cheapest receiver for the collection of this and other gases is a moistened bladder, with a piece of tobacco-pipe firmly tied into its neck, and twisted in such a manner as to expel all the common air. This may easily be adapted to any vessel by means of the pipe, which may be fixed in the cork, and closely luted in the usual way.

2. *Hydrogen Gas*.—If some iron wire be put into a phial with three or four ounces of water, and a little sulphuric acid be poured upon the contents, hydrogen gas will be evolved. It may also be procured as follows :—

3. Put a quantity of filings of zinc into a vessel which has a glass tube adapted to it; then pour upon the sulphuric acid that has been diluted with six or eight times its quantity of water, an effervescence will immediately take place, the water will be decomposed, the oxygen of oil will become united to the metal, and the hydrogen gas will be disengaged by the glass tube into any proper receiver.

Obs.—Hydrogen gas can only be procured pure from water, which in all cases must suffer a decomposition. From its great levity, hydrogen has generally been used to fill air balloons: one hundred cubical inches of it weigh only two grains and one quarter.—See p. 173.

4. *Sulphuretted Hydrogen*.—To procure sulphuretted hydrogen gas, put some sulphuret of iron into a phial; pour a little sulphuric acid over it, and attach a bladder to the phial; a gas of the above description, extremely fetid and disagreeable, will be evolved; though the ingredients here employed were destitute of smell.—Also,

5. *Sulphuretted Hydrogen* may be obtained by melting together in a crucible three parts by weight of iron filings and one of sulphur; reduce the mass to powder, and put it, with a little water, into a glass vessel with two mouths: lute one end of a crooked glass tube into one of these mouths, and let the extremity of the tube pass under a glass jar in a pneumatic trough (see *fig. 7. pl. III.*), the jar being inverted full of water. Then pour diluted muriatic acid through the other mouth of the vessel, which must be immediately closed up. The gas will now be abundantly disengaged and flow into the glass jar, displacing the water. For a more ready way of forming sulphuretted hydrogen gas, see *Gay-Lussac, in Annales de Chim. et Phys.* tome vii. p. 314. See *Compounds of Hydrogen and Sulphur*, p. 199, *et seq.*

6. *Oxygen Gas*.—To procure oxygen gas in abundance, put an ounce or two of the black oxide of manganese into a small glass retort, and pour a little concentrated sulphuric acid upon it, and apply the heat of a lamp.—See p. 167.

7. *To collect pure oxygen gas*.—If the leaves of a plant, fresh gathered, be placed in the sun, as hereafter directed, very pure oxygen gas may be collected.

Obs.—The upper side of the leaf, is the organ of respiration: hence some vegetables (as they give out oxygen only in the day) close the upper surfaces of their leaves during the night. The multiplicity of the leaves of trees indicates the importance of transpiration to a vegetable. This fact, we believe, was first announced by Dr. Priestley. He had observed that a plant called a *conferva*, which exists in pools of water, when exposed to the rays of the sun, is covered with minute globules of water filled with air; and when he inverted a glass filled with water over the slender filaments of this plant, he obtained the gas collected in the upper part of the glass, and found it to be pure oxygen gas, which he proved by the difference there was in the burning of a lighted taper when immersed in this gas, and in atmospheric air.

8. *To shew the production of oxygen from the leaves of plants*.—Fill a glass bell with water, introduce some fresh leaves under it, and place the bell inverted in a flat dish of water. Expose the apparatus to the rays of the sun, and very pure oxygen gas will be disengaged, which will displace the water in the jar, and occupy its place. In like manner a sprig of mint, corked up with a small portion of carbonic acid air, and placed in the light, will absorb the carbon and render the air again capable of supporting life. The plant purifies what the animal has poisoned.

Obs.—It is to be remarked that all the oxygen

is not given out by plants; part must be retained to form the sugar and acids which are found in vegetables. Mr. Cruickshank has shown by experiment, that oxygen is absolutely necessary for the conversion of mucilage into sugar.

9. *Ammoniacal Gas*.—Put a mixture of two parts of quick lime, and one of muriate of ammonia, both in powder, into a small glass retort; apply the heat of a lamp, and ammoniacal gas. See p. 194.

10. *Sulphurous Acid Gas*.—Pour a little sulphuric acid upon a small quantity of quicksilver in a glass retort, apply heat, and sulphurous acid gas may be collected. See p. 97.

11. *Nitrous acid Gas*.—Take a few shreds of copper, or some copper wire, and pour over them a little diluted nitrous acid, in the proportion of about three parts of water to one of acid. The gas that is evolved is nitrous gas. See p. 97.

12. *Nitric Acid Gas*.—Pour some sulphuric acid upon an ounce or two of the nitrate of potash in a glass retort; apply heat by means of a lamp, and collect nitric acid. See p. 97.

13. *Muriatic Acid Gas*.—Pour some sulphuric acid over muriate of soda, and treat in the same manner, and muriatic acid in the gaseous form will rise from the retort. See p. 95.

14. Convey some muriatic acid gas into a jar containing a portion of the gas produced in experiment No. 9. From the mixture of these two invisible gases, a solid substance, the common sal ammoniac, will be produced. It may be seen depositing itself upon the sides of the vessel in a neat crystallized form.

Obs.—Muriatic or acetic acid are the usual tests employed to discover the presence of ammonia, which will produce very evident white fumes.

15. Whenever uncombined muriatic, or any volatile acid is suspected to be present in any chemical mixture, it may be detected by ammonia. A single drop of ammonia on a feather,

or small slip of paper, held over the mixture, will immediately render the vapour visible.

Obs.—Ammonia is of use in making archil, an article in great demand with dyers. About the year 1300, a Florentine merchant having accidentally observed that stale urine, which always contains ammonia, imparted a very fine colour to a certain species of moss, he made experiments, and thus learned to prepare archil.* It is said that this alkali will give to *new* brandy all the qualities of that of the oldest date. This method consists in pouring five or six drops of liquor ammonia into each bottle of brandy, and shaking it well, that it may combine with the acid, on which the taste and other qualities of the new liquor depend.† See p. 195.

16. *To convey an idea of the principle upon which Balloons are inflated.*—Procure a bladder furnished with a stop-cock (*Pl. I.*), fill it with hydrogen gas, and then adapt a tobacco-pipe to it; and by dipping the bowl of the pipe into a lather of soap, and compressing the bladder, soap bubbles will be formed, filled with hydrogen gas.

17. Get a bladder similar to the one described in the last experiment, and charge it with a mixture of hydrogen and oxygen gases: with this apparatus blow up soap bubbles as before, and touch them with a lighted match.

Obs.—Hydrogen is not combustible unless it be mixed with atmospheric air, or with some others of the supporters of combustion; for without such previous admixture, it is absolutely destructive of flame, as may be proved by immersing a lighted taper in a phial of hydrogen gas (from which the utmost care has been taken

* Berthollet's Elements of the Art of Dyeing.

† Bib. Phys. Econ.

to exclude the presence of atmospheric air), which will be extinguished the moment it comes in contact with the pure hydrogen gas. See p. 171.

18. *To produce a pencil of Flame.*—Fill a bladder, similar to the one already described (page 263), with hydrogen gas; apply a lighted match to the end of the tobacco-pipe, and press the bladder gently. An extremely beautiful pencil of flame will be seen issuing from the pipe, till the whole of the hydrogen gas is consumed.

19. *To cause a brilliant combustion.*—Get such a glass jar as is generally used for deflagrating the gases, and fill it with oxy-muriatic acid gas. If nickel, arsenic, or bismuth, in powder, be thrown into this gas, and the temperature of the atmosphere be not lower than 70° , the metal will inflame, and continue to burn with the most brilliant combustion.

20. Put a small piece of phosphorus into a crucible, cover it closely with carbonate of lime or pulverized common chalk, so as to fill the crucible. Upon this invert another crucible, and subject both to the fire. When the whole has become perfectly red hot, remove them from the fire: and on examining them when cold, the carbonic acid of the chalk will have been decomposed, and the black charcoal, the basis of the acid, may easily be perceived amongst the materials.

21. Take one of the glass receivers, generally adopted for deflagrating the gases; fill it with oxygen gas, and invert it in a shallow pan of water. Then having ready ignited a piece of the tortual part of charcoal, suspend it by a wire to the stopper of the receiver, and immerse it quickly in the gas. The charcoal will be seen to burn for a considerable time with the greatest splendour, throwing out the most beautiful coruscations. When the inflammation is over, the oxygen gas will be consumed, and the water will be found to be impregnated with carbonic acid; and if some transparent lime-water be poured in, the whole will become opaque from the carbonate of lime now formed.

22. *Invisible Gas.*—Place a lighted wax taper within a narrow glass jar, then take a jar or phial of carbonic acid gas,

and cautiously pour it into the jar containing the taper. This being an *invisible gas*, the operator will appear to invert merely an empty vessel, though the taper will be as effectually and instantaneously extinguished as if water itself had been used.

Obs.—Carbonic acid has with other properties, that of rendering lime soluble in water. And plants of all kinds give out carbonic acid gas while growing; but when assisted by the rays of the sun, there is reason to think that plants have the power of decomposing this acid; for there the leaves give out only oxygen gas. —*Annales de Chimie*, tome xiii. page 318.

23. *Invisible Gases rendered visible.*—Upon some acetate of potash in a saucer, pour sulphuric acid. Into another saucer put a mixture of about two-parts of quick-lime, and one of sal-ammoniac, both in powder, adding to those a *very small* portion of boiling water. Both saucers, while separate, will yield *invisible gases*; but the moment they are brought close together, the operator will be enveloped in very visible vapours. Muriate of soda, in this experiment, may be substituted for acetate of potash.

24. If a glow-worm be placed within a jar of oxygen gas, in a dark room, the insect will shine with much greater brilliancy than it does in atmospheric air, and appear more alert. As the luminous appearance depends on the will of the animal, this experiment may, probably, afford an instance of the stimulus which this gas communicates to the animal system.

25. *Formation of an Acid by the mixture of two Gases.*—Let a slip of litmus paper be pasted within a glass jar near the bottom; then fill the jar with water, and invert it on the shelf of a pneumatic trough. If as much nitrous gas, previously well washed, be passed into the jar as will displace the water below the level of the paper, the colour of the litmus paper will

still remain unaltered; but on passing up atmospheric air, it will immediately be reddened.

Obs.—The nitrous acid gas was used by Dr. Priestley for purposes of eudiometry. The first eudiometer was made in consequence of his discovery, that when nitrous gas is mixed with atmospheric air over water, the bulk of the mixture diminishes rapidly, from the combination of the gas with the oxygen of the air, and the absorption of the nitric acid thus formed. Whenever nitrous acid is thus mixed with atmospheric air, the diminution will be in proportion to the quantity of the oxygen; of course this jar will always indicate the measure of oxygen present in any portion submitted to trial. In consequence, however, of some inconveniences attending the use of this eudiometer, others have been invented by Scheele, Dr. Marte, Humboldt, Seguin, Berthollet, and Davy.

26. *To show the necessity of Water in some chemical experiments.*—Take a few grains of citric acid, and twice as much carbonate of potash, or of soda, both in powder; mix them and put them into a dry glass. No chemical change will take place in either of these salts; but the moment water is poured upon them, an effervescence and extrication of gas will ensue.

III. EXPERIMENTS ON THE FORMATION AND CRYSTALLIZATION OF SALTS.

1. *To show that a determinate figure has been instamped upon every individual salt.*—Dry and reduce to powder common Glauber's salt, and then dissolve in three times its weight of boiling water; and it will not only be found to crystallize on cooling, but the crystals will assume the identical forms which they exhibit before they were pulverized.

2. *To prevent Crystallization.*—Let three-quarters of an ounce of Glauber's salt be dissolved in two ounces of boiling water, pour it while hot into a phial, and cork it close. In this state it will not crystallize, even when perfectly cold; but if the cork be now removed, the crystallization will be seen to commence and proceed with rapidity; affording an instance of the effect of atmospheric air on crystallization.

Obs.—In crystallizing salts in the large way, the manufacturers have remarked that the largest crop of crystals is always found on that side of the cooler which is exposed to the most light; and that in crystallizing some salts, if the vessel be partially shaded, the line of interception will be evident, and the part excluded from the light distinctly marked by the limit of the crystallization.

3. *To shew that saline Solutions give out Caloric in the act of crystallization.*—Repeat the above experiment (No. 2) with a small thermometer immersed in the solution, and closed so as to exclude the atmospheric air. If the solution be suffered to cool completely under these circumstances, the thermometer will be seen to rise on the removal of the cork.

Obs.—Caloric pervades all bodies: this is not the case with any other substance we know of; not even light. It lies hidden in every thing around us. It is a substance which we are ever in want of; it is, therefore, deposited on every side, and is ready for every exigency. As it penetrates bodies it frequently forms a chemical combination with them, and becomes essential to their composition. This is always the case when a solid is converted to a liquid, or when a liquid passes to a gaseous state. But if caloric be superadded to a body when in a state of saturation, it merely traverses its surface, and passes

from it, in the form of sensible heat, to some of the adjacent bodies. See p. 18.

4. *An Instance of a metallic Solution by means of an Acid, in which the Opacity of a metallic Body is completely overcome, and the whole rendered perfectly transparent.*—Let half an ounce of quicksilver be put into a wine glass, and pour about an ounce of diluted nitrous acid upon it. The nitrous acid will be decomposed by the metal with surprising rapidity; the colour of the acid will be quickly changed to a beautiful green, while its surface will exhibit a dark crimson; and an effervescence indescribably vivid and pleasing will go on during the whole time the acid operates upon the quicksilver. When a part only of the metal is dissolved, a change of colour will again take place, and the acid by degrees will become paler, till it is as pellucid as pure water.

5. *An Instance of the formation of a metallic Salt.*—Take the metallic solution formed in the last experiment (No. 4), and add a little more quicksilver to saturate the acid; then place it at some distance over the flame of a lamp, so as gently to evaporate a part of the water. The new formed salt will soon be seen to begin to shoot into needle-like prismatic crystals, crossing each other in every possible direction.

6. *A transparent Liquid holding a Metal in solution.*—Pour a small quantity of strong nitrous acid into a wine-glass, add twice its quantity of distilled or clear rain water, and, when mixed, throw a few very small pieces of granulated tin into it. A violent effervescence will take place, the lighter particles of the tin will be thrown to the top of the acid, and be seen to play up and down in the liquor for a considerable time till the whole be dissolved.

7. *An Example of the difference of Colour of metallic Oxides, arising from different degrees of oxidizement.*—Let an ounce of quicksilver be dissolved, *without heat*, in three quarters of an ounce of strong nitrous acid, previously diluted with one ounce and a half of water. Dissolve also the same weight of quicksilver, *by means of heat*, in the same quantity of a similar acid, and then to each of these colourless solutions

add a solution of potash. In the first case, the metal will be precipitated in a *black*, in the other in a *reddish-yellow powder*, affording an example of the difference of colour arising from different degrees of oxidizement.

8. *To form a mild Salt from a mixture of two corrosive Substances.*—Take an ounce of a solution of caustic soda, pour upon it half an ounce of sulphuric acid; lay the mixture aside, and when cold, crystals of sulphate of soda will be formed in the liquor.

9. *To produce an inodorous and tasteless Salt, &c.*—Take carbonate of ammonia (the common volatile smelling salt) and pour upon it muriatic acid so long as any effervescence continues. The produce will be a solid salt, perfectly *inodorous*, and of little taste.

10. *To make a solid mass from two transparent fluids.*—Mix in a wine glass equal quantities of a saturated solution of muriate of lime, and a saturated solution of carbonate of potash, both transparent fluids; stir the mixture, and a solid mass will be the result.

11. *To convert a solid opaque mass by means of a chemical agent to a transparent liquid.*—Take the substance produced in the preceding experiment, and pour a very little nitric acid upon it. The consequence will be the solid matter will be again taken up, and the whole will exhibit the appearance of one homogeneous fluid.

12. *To make a solid from two fluids.**—Take a transparent saturated solution of sulphate of magnesia (Epsom salt), and pour into it a similar solution of caustic potash or soda. The mixture will almost immediately become solid.

13. Take caustic soda one ounce, and saturate it with muriatic acid: the result from the union of these two corrosive substances will be our common table salt.

IV. EXPERIMENTS ON COLOURS.

1. *To produce three different colours from the same vegetable infusion merely by the addition of three colourless*

* This sudden conversion of two fluids to a solid, and that in the preceding experiment, have been called chemical miracles.

fluids.—Pour boiling water upon a red cabbage, sliced, and when cold pour the clear infusion into three wine glasses. To one add a solution of alum, to another a little of the solution of potash, and to the third a few drops of muriatic acid. The liquor in the first glass will assume a purple, the second a bright green, and the third a beautiful crimson.

2. *An instance of the effects of acids and alkalies in changing vegetable colours*.—Put a little of the tincture of litmus, the colour of which is a bright blue with a tinge of purple, into a phial, and add to it a few drops of diluted muriatic acid; its colour will change to *vivid red*. Add a little solution of potash; the red will now disappear, and the *blue* will be restored. By these means the liquor may be changed alternately from a red to a blue, and *vice versâ* at pleasure. See page 65.

3. *A test for alkalies and acids*.—Make an infusion of red roses, violets, or mallow flowers; add a solution of potash and it will become *green*; the addition of diluted muriatic acid will immediately turn it *red*.

Obs.—This experiment may be as often varied as the preceding one.

4. *A tincture by which the most minute portion of any alkali in solution may be detected*.—To tincture of turmeric add a drop or two of solution of potash; the tincture will change its original bright *yellow colour* to a dark *brown*: a little colourless diluted acid will restore it.

5. *To make the true Prussian blue*.—Into a wine glass of water add a few drops of the prussiate of potash; and into a second glass a little dilute solution of sulphate of iron: by adding these two *colourless fluids* together, a bright deep blue colour will immediately be produced, which is the true Prussian blue.

6. *To produce Yellow from two colourless fluids*.—Add prussiate of potash and nitrate of bismuth, both colourless fluids, and a yellow will be the product.

7. *To produce a true prussiate of copper*.—Pour a little prussiate of potash into a glass containing a *colourless* solution

of sulphate of copper, and a reddish brown will be produced, being a true prussiate of copper.

8. *To produce a Black from two transparent colourless fluids.*—Prepare a phial with pure water and a little tincture of galls, and another with a weak solution of sulphate of iron; then mix these transparent colourless fluids together, and they will instantly become black.

9. *From two blue fluids to produce a Red.*—Pour a little tincture of litmus into a wine-glass, and into another some diluted sulphate of indigo; add these two blue fluids together, and the mixture will become perfectly red.

10. *To produce an intense Blue.*—Drop as much sulphate of copper into water as will form a colourless solution; then add a little ammonia, equally colourless, and an intense blue colour will arise from the mixture.

11. *Prussian Blue.*—Take water holding carbonate of iron in solution, and add some diluted prussiate of potash: Prussian blue will be formed by the mixture.

12. (a) Take some of the same water as that used in the last experiment, boil it, and now add prussiate of potash: in this case no colour will be produced.

13. *To change blue to red.*—Take some water impregnated with carbonic acid, and add to it a little blue tincture of litmus. The whole will be changed to a red.

14. (b) Take some of the same carbonated water, and boil it; then add a little tincture of litmus, and the blue colour will experience no change.

15. *To discharge and restore a colour.*—Take some of the black liquid described in Experiment 8., add by degrees muriatic acid to it, and the colour will be discharged. Now drop in a little solution of potash, and the black colour will be restored.

Obs.—Some nicety is requisite in adding the acid and alkali; for if they be given in excess, the effects will not be so apparent.

16. (c) Take the blue solution formed by the Experiment 10., add a little sulphuric acid, and the colour will disappear;

pour in a little solution of caustic ammonia, and the blue colour will be restored. Thus may the liquor be alternately changed at pleasure.

17. *To produce a beautiful green flame.*—If a spoonful of good alcohol and a little boracic acid be stirred together in a tea-cup, and then set on fire, they will produce a very beautiful green flame.

18. (d) If alcohol be inflamed in like manner with a little pure strontites in powder, or any of its salts, the mixture will give a carmine flame.*

19. *A brilliant yellow flame.*—Barytes forms some of the most useful chemical tests in solution with water, and various acids. In muriatic acid it is used medicinally. It is capable of making a very tenacious cement, but has not yet been used in the arts, except by limners as a most excellent water colour. Barytes is also similar to the alkalies in changing red vegetable colours to a violet or blue, and yellow vegetable colours to a brown; in rendering oil mixable with water, in forming glass with silica, in its solubility in water, and in the readiness with which it shoots into crystals. Pure barytes will decompose sulphate of potash or sulphate of soda. If barytes be used instead of strontites, we shall have a brilliant yellow flame.

20. *A reddish yellow flame.*—If alcohol contains muriate of magnesia, it has the property of burning with a reddish-yellow flame.

21. (e) *Change of colours.*—Evaporate to dryness a solution of gold, made with nitro-muriatic acid, and dissolve the crystals in a sufficiency of pure water to prevent the crystallization of the metallic salt.—Thoroughly moisten a little magnesia with this aqueous solution, and place the mixture in the sun's rays. A change of colour will soon be apparent: it will first take a faint violet hue, and in a few hours the whole will have acquired a very deep purple.

22. (f) Moisten a little magnesia with some of the solution

* If moisture be present in the mixture of strontites with inflammable bodies, the flame will be of a carmine colour. Thus, if this earth, or the salts formed with it be dissolved in alcohol, the spirit will burn with a flame of this colour. This distinguishes it from barytes.

as before, and then dry the mixture in the *dark*. If it be then submitted to the action of the sun's rays, it will acquire only a faint violet, even by several hours exposure.

23. (*g*) If the mixture employed in the last experiment (*f*) be now thoroughly *wetted* with pure water, and again placed within the rays of the sun, its colour will rapidly change, and it will acquire a deep purple approaching to crimson.

24. (*h*) Moisten a piece of white riband with the aqueous solution of gold described at No. 21, and dry it thoroughly in the dark; then suspend it in a clean, dry, transparent phial, cork it close with a dry cork. Expose the riband thus secured to the strong light of the bright sun for half an hour, and only a faint appearance of change of colour will be perceived.

25. (*i*) Take the riband out of the phial that was employed in the last experiment, and *wet* it well with distilled water. If it be now exposed to the sun's rays, it will instantly change colour, and will quickly be stained of an indelible purple.

V.—EXPERIMENTS IN DYEING AND CALICO-PRINTING.

1. (*a*) Pour a little solution of indigo in sulphuric acid into a glass of water, and add about an equal quantity of solution of *carbonate of potash*. If a piece of white cloth be dipped in this mixture, it will come out a blue. If a piece of yellow cloth be dipped in, it will become green, or a red will be converted to a purple. A slip of blue litmus paper immersed in it will immediately become red.

2. (*b*) If a little fustic, quercitron bark, or other dye, be boiled in water, the colouring matter will be extracted, and a coloured solution formed. On adding a small quantity of dissolved alum to this decoction, the alumina, or base of the salt, will attract the colouring matter, forming an insoluble compound, which in a short time will subside, and may easily be separated.

3. (*c*) Boil a little cochineal in water, with a grain or two of cream of tartar, (supertartrate of potash,) and a dull kind of crimson solution will be formed. By the addition of a few

drops of nitro-muriate of tin,* the colouring matter will be precipitated of a beautiful scarlet.

Obs.—This, and some of the former instances, will give the student a tolerably correct idea of the general process of dyeing wollen cloth.

4. (d) *An example of the process of bleaching coloured goods.*—If a few strips of dyed linen cloth of different colours be dipped into a phial of oxymuriatic acid, the colours will be quickly discharged; for there are few colours that can resist the energetic effect of this acid.

5. (e) *To preserve the original colour and discharge others.*—Having found a piece of blue linen cloth that will bleach in oxygenized muriatic acid, dip the tip of the finger in a solution of *muriate of tin*, and press it while wet with the solution, upon a strip of this cloth. After an interval of a few minutes immerse the cloth in a phial of liquid oxymuriatic acid, and when it has remained in it the usual time, it will be found that the spot which was previously wet with muriate of tin, has preserved its original colour, while the rest of the cloth has become white.

6. (f) *A permanent Black.*—Dip a piece of white calico in a strong solution of acetate of iron, dry it by the fire, and lay it aside for three or four days. After this wash it well in hot water, and then dye it black by boiling it for ten minutes in a strong decoction of Brazil wood. If the cloth be now dried, any figures printed upon it with a *colourless* solution of muriate of tin, will appear of a beautiful scarlet, although the ground will remain a permanent black.

7. (g) *A permanent Blue.*—Let four drachms of sulphate of iron be dissolved in one pint of cold water, then add about six drachms of lime in powder, and two drachms of finely pulverized indigo, stirring the mixture occasionally for 12 or

* Tin is used by dyers to give a brightness to cochineal, archil and other articles used for dyeing reds and scarlets; and to precipitate the colouring matter of other dyes. For these purposes it is previously dissolved in a peculiar kind of aquafortis, called dyer's spirit.

14 hours. If a piece of white calico be immersed in this solution for a few minutes, it will be dyed green; and by exposure to the atmosphere only for a few seconds, this will be converted to a permanent blue.

8. *Calico-printers' buff*.—If a piece of calico be dipped in a solution of sulphate of iron, and when dry washed in a weak solution of carbonate of potash, a permanent colour will be produced, viz. the buff of the calico-printers.

9. *Nankeen dye*.—Boil equal parts of arnotto and common potash in water till the whole is dissolved. This will produce the pale reddish buff, so much in use, and sold under the name of nankeen dye.

10. If muriate of tin,* newly made, be added to a solution of indigo in sulphuric acid, the oxygen of the indigo will be absorbed, and the solution instantly converted to a *green*. It is on the same principle that muriate of tin is employed in cleansing discoloured leather furniture; as it absorbs the oxygen, and the leather is restored to its natural colour.

11. Take a piece of very dark olive-coloured linen that has been dyed with iron and quercitron bark, or weld, and spot it in several places with a *colourless* solution of muriate of tin. Wherever the cloth has been touched with this solution, this original colour will be discharged, and spots of a bright yellow will appear in its stead.

12. *To show the effect of acids in discharging vegetable colours*.—Dip a piece of white calico in a cold solution of sulphate of iron, and suffer it to become entirely dry. Then imprint any figures upon it with a strong solution of colourless citric acid, and allow this also to dry. If the piece be then well washed in pure warm water, and afterwards boiled in a decoction of logwood, the ground will be dyed either of a slate or black colour, according to the strength of the metallic solution, while the printed figures will remain beautifully white.

* Tin is soluble in all the mineral acids. It may be precipitated from its solutions by potash, but an excess of potash will re-dissolve the metal. Nitro-muriate of gold is a test for the presence of tin, in solution with which it forms a fine purple precipitate.

13. If lemon juice be dropped upon any kind of buff colour, the dye will be instantly discharged. The application of this acid by means of the block, is another method by which calico-printers give the white spots or figures to piece-goods. The crystallized acid is generally used for this purpose.

Obs.—These experiments will give the student some idea of the nature of calico-printing.

VI. COMBUSTION AND DETONATION.

1. Spread a piece of tinfoil, such as is used for coating electrical jars, upon a piece of thick paper; spread some powdered crystals of nitrate of copper upon it, and sprinkle it with water. Fold it up quickly, and wrap it round carefully with the paper, more effectually to exclude the atmospheric air. Place it then upon a tile, and in a short time *combustion* will commence, and the tin will inflame.*

2. Take three sorts of nitre, two of potash, and one of sulphur (all of these should be thoroughly dry); then mix them by rubbing them together in a warm mortar: the resulting compound is called *fulminating powder*. If a little of this powder be placed upon a fire-shovel over a hot fire, it gradually blackens, and at last melts. At that instant it explodes with a violent report.

Obs.—This mixture is not dangerous like the metallic fulminating powders; none of which should be intrusted in the hands of young people.

3. If a few pounds of a mixture of iron filings and sulphur be made into paste with water, and buried in the ground for a few hours, the water will be decomposed with so much rapidity, that combustion and flame will be the consequence.

4. Put a little *fresh calcined* magnesia in a tea-cup upon the hearth, and suddenly pour over it as much concentrated sul-

* Tin is much more combustible than many of the metals. It will burn in oxygen gas before it acquires a heat sufficient to fuse it.

phuric acid as will cover the magnesia. In an instant sparks will be thrown out, and the mixture will be completely ignited.

5. Make a little charcoal perfectly dry; pulverize it very fine, and put it into a warm tea-cup. If some strong nitrous acid be now poured upon it, combustion and inflammation will immediately ensue.

Obs.—Charcoal, from its affinity with oxygen, will decompose the nitric and sulphuric acid. It decomposes the latter with great rapidity. If the charcoal be dry and finely powdered and the acid strong, and allowed to run down the inner side of the vessel to mix with the charcoal, it will burn rapidly, giving out a beautiful flame, and throw up the powder so as to resemble a brilliant fire-work.

6. If strong nitrous acid be poured upon a small quantity of a mixture of oxymuriate of potash and phosphorus, flashes of fire will be emitted at intervals for a considerable time.

7. Put a bit of phosphorus into a small phial, then fill it one-third with boiling olive oil, and cork it close. Whenever the stopper is taken out in the night, light will be evolved sufficient to show the hour upon a watch.

8. Burn a piece of iron wire in a deflagrating jar of oxygen gas, and suffer it to burn till it goes out of itself. If a lighted wax taper be now let down into the gas, this will burn in it for some time, and then become extinguished. If ignited sulphur be now introduced, this will also burn for a limited time. Lastly, introduce a morsel of phosphorus, and combustion will also follow in like manner.

Obs.—These experiments demonstrate the relative combustibility of different substances.

9. *Argentine Flowers.*—When antimony is heated to whiteness in a crucible, and in this state agitated, in contact with the air, it inflames with a sort of explosion, and presents

while burning a very singular kind of white flame, forming what have been formerly called *argentine flowers*.

10. When antimony is well fused upon charcoal, if, at the moment when its surface is not covered with any particle of oxide, we throw it suddenly upon the ground, the globules into which it divides in its fall, burn with a very lively flame, throwing out on all sides brilliant sparks, different from that of any other metal.

Obs.—Antimony combines with phosphorus by fusion; but the compound, which is brittle and has the metallic lustre, has not yet been found useful. (See Pelletier in *Annales de Chimie*, tome xiii.) Sulphur and antimony also combine by fusion, and form a substance exactly similar to the native sulphuret of this metal. It has a metallic appearance, but is much more fusible than antimony. Proust and Vauquelin make it consist of antimony 44, sulphur 16.

11. Mix five or six grains of sulphuret of antimony with half its weight of oxymuriate of potash, and then, if a sudden stroke be given to the mixture, upon a steel anvil, it fulminates with a loud report, emitting, according to Fourcroy, a flame as brilliant and rapid as lightning.

12. Into a tea-cup placed upon a hearth, and containing about a table spoonful of oil of turpentine, pour about half the quantity of strong nitrous acid, previously mixed with a few drops of sulphuric acid. The moment the acids come in contact with the turpentine, heat and flame will be produced.

Obs.—In performing this experiment it is advisable to mix the acids in a phial, to tie the phial to the end of a stick, and, at arm's length, to pour its contents into the oil, as the sudden combustion sometimes occasions a part of the liquids to be thrown out of the vessel.

13. Pour a little pure water into a small glass tumbler, and put one or two small pieces of phosphuret of lime into it. In

a short time flashes of fire will dart from the surface of the water, and terminate in ringlets of smoke, which will ascend in regular succession.

Obs.—If a piece of phosphorus be placed on the surface of a little water below the heat of *boiling* it will immediately inflame. This is one characteristic of phosphorus, and distinguishes it from all other substances. It melts at the temperature of 90° , and takes fire at about 148° .—See p. 187.

14. *To show the extreme inflammability of phosphorus.*—Put thirty grains of phosphorus into a Florence flask, with three or four ounces of water. Place the vessel over a lamp, and give it a boiling heat. Balls of fire will soon be seen to issue from the water, after the manner of an artificial fire-work, attended with the most beautiful coruscations.

15. Pour four ounces of pure water into an eight-ounce retort, add a little solution of pure potash, and give it a boiling heat with a lamp. When it boils, drop a small piece of phosphorus into it, and immerse the beak of the retort in a vessel of water. Bubbles of phosphuretted hydrogen gas will issue from the retort, rise through the water, and take fire the moment they come in contact with atmospheric air, somewhat similar to the appearance mentioned in experiment No. 13.

16. Fix a small piece of solid phosphorus in a quill, and write with it upon paper. If the paper be now carried into a dark room, the writing will be beautifully luminous.

17. Pour a little phosphuretted ether upon a lump of sugar, and drop it into a glass of water a little warm. The surface of the water will soon become luminous; and if it be moved by blowing gently with the mouth, beautiful and brilliant undulations of its surface will be produced, exhibiting the appearance of a liquid combustion.

18. If any part of the body be rubbed with liquid phosphorus, or phosphuretted ether, that part, in a dark room, will appear as though it were on fire, without producing any dangerous effect, or sensation of heat.

19. *Detonating Powder.*—Take two grains of oxymuriate or chlorate of potash,* and one grain of flowers of sulphur; rub them together in a mortar, and a smart detonating noise will be produced. Continue to rub the mixture hard, and the reports will be frequently repeated, accompanied with vivid flashes of light. If the same mixture be wrapped in paper, laid on an anvil, and smartly struck with a hammer, the report will be as loud as what is usually produced by the firing of a pistol.

20. Take two grains of chlorate of potash, and one grain of phosphorus. Treat this mixture as in the last experiment, and very violent detonations will be produced.

Obs.—It is advisable *never to exceed* the quantity of phosphorus prescribed here, and in other similar experiments.

21. Take a similar quantity of chlorate of potash with three or four grains of flower sulphur, and mix the ingredients very well on paper. If a little of this mixture be taken up on the point of a knife and dropped into a wine-glass containing some sulphuric acid, a beautiful column of flame will be perceived, the moment the powder comes in contact with the acid.

22. *Combustion under Water.*—Put a little oxymuriate of potash and a bit of phosphorus into an ale-glass, pour some cold water upon them cautiously, so as not to displace the salt. Now take a small glass tube, and plunge it into some sulphuric acid; then place the thumb upon the upper orifice,

* Chlorate of potash is used not only for experiment but also in medicine. From its explosive effects, Berthollet was induced to propose it as a substitute for nitre in the manufacture of gunpowder. The attempt was made; but no sooner did the workmen begin to triturate the mixture, than it exploded with violence, and proved fatal to two individuals who were near it.—*Phil. Trans.* vol. xcii. p. 128. Notwithstanding this accident, which happened in the year 1788, the French, we are informed, have actually employed in one of their campaigns, gunpowder made with chlorate of potash instead of saltpetre. This is practicable, as has been proved in this country by the Rev. Alexander Forsyth of Belhelvie, in Aberdeenshire, who took out a patent for a new kind of gun-lock, to be used without a flint, which inflames the gunpowder merely by percussion.

acid in this state withdraw the tube, which must be instantly immersed in the glass, so that, on removing the thumb, the acid may be immediately conveyed upon the ingredients. If a morsel of the phosphuret of lime be added, there will be combustion also on the surface of the water.

23. *To produce instantaneous flame.*—Prepare a mixture of equal parts of lump sugar and oxymuriate of potash; put a small quantity of this mixture upon a plate or a tile; then dip a piece of sewing-thread into a phial of sulphuric acid, so as to convey the smallest quantity of the acid; with this touch the powder, and an immediate burst of flame will be the consequence.

24. *To produce detonation and flame by the mixture of a powder with cold water.*—Mix, without much friction, ten grains of chlorate of potash with one grain of phosphorus, and drop the mixture into concentrated sulphuric acid. This is an instance of detonation and flame being produced by the mixture of a powder with a cold liquid.

25. Add a few grains of chlorate of potash to a tea-spoonful or two of alcohol, drop one or two drops of sulphuric acid upon the mixture, and the whole will burst into flame, forming a very beautiful appearance.

26. A mixture of chlorate of potash and arsenic furnishes a detonating compound, which takes fire with the utmost rapidity. The salt and metal, first separately powdered, may be mixed by the gentlest possible triture, or rather by stirring them together on paper with the point of a knife. If two long trains be laid on a table, the one of gunpowder and the other of this mixture, and they be in contact with each other at one end, so that they may be fired at once; the arsenical mixture burns with the rapidity of lightning, while the other burns, with comparative slowness.

Obs.—Of the chlorate of potash, Fourcroy remarks, that it “seems to include the elements of thunder in its particles. A chemist can produce effects almost miraculous by its means, and nature seems to have concentrated all his power of

detonation, fulmination, and inflammation in this terrible compound." Too great caution cannot be observed in the use of this salt. By *gently* tritulating three grains of it, and one of sulphur, in a mortar with a metallic pestle, a series of detonations takes place resembling the cracks of a whip. If struck upon an anvil, the report is as loud as a pistol. Three parts of it, with half a part of sulphur and half a part of charcoal, produce most dreadful and violent explosions. If this mixture be thrown into concentrated sulphuric acid, a flame is produced so brilliant and strong that the eye can with difficulty support it. (*Fourcroy's Elements of Chemistry*, p. 313.) The shocking death of the two individuals alluded to in page 270, and the burns which others have suffered by it, render it feared by chemists in general. The above mixture, it should be remembered, ought always to be made moist, and never kept *ready* mixed, as it is liable to spontaneous explosion.

27. Into an ale-glass of water put a few pieces of zinc, and a small bit of phosphorus; then drop a little sulphuric acid upon the mixture by means of a glass tube, as described at No. 21, and phosphuretted hydrogen will presently be disengaged, which will inflame on rising to the surface of the water.

Obs.—Dr. Thompson, to whom we are chiefly indebted for our knowledge of the properties of this gas, gives the following directions for obtaining it:—Fill a small retort with water, acidulated by muriatic acid, and then throw into it a quantity of phosphuret of lime in lumps. Plunge the beak of the retort under water, and place over it an inverted jar filled with that liquid. Phosphuretted hydrogen gas is extricated in considerable quantity, and soon fills the

glass jar. Half an ounce of phosphuret of lime yields about 70 cubic inches of this gas.— (*Thompson's System of Chemistry*, vol. i. p. 272.) It may also be formed by boiling a little phosphorus in a solution of pure potash. The water is decomposed thereby and furnishes the hydrogen. The retort should nearly be filled with the solution, otherwise the gas will inflame.

28. Take a small piece of phosphuret of lime a little moistened by the air, and let a single drop of concentrated muriatic acid fall upon it. In this case phosphuretted hydrogen will also be evolved, accompanied by small balls of fire darting from the mixture, and the most intolerably fetid smell that can be conceived.

29. If twenty grains of phosphorus, cut very small, and mixed with forty grains of finely granulated zinc, be put into four drachms of water, and two drachms of concentrated sulphuric acid be added thereto, bubbles of inflamed phosphuretted hydrogen gas will quickly cover the whole surface of the fluid in succession, forming a real aqueous fountain of fire.

30. If any light substance capable of conducting heat, be placed upon the surface of boiling water, and a bit of phosphorus be laid upon it, the heat of the water will be sufficient to set the phosphorus on fire.

31. If one grain of dry nitrate of bismuth be previously mixed with a grain of phosphorus, and then rubbed together in a metallic mortar, a loud detonation will be produced.

32. Drop a piece of phosphorus about the size of a pea into a tumbler of hot water, and from a bladder, furnished with a stop-cock, force a stream of oxygen gas directly upon it. This will afford the most brilliant combustion under water that can be imagined.

33. Put a little alcohol in a tea-cup, set it on fire, and invert a large bell-glass over it. In a short time an aqueous vapour will be seen to condense upon the inside of the bell, which, by means of a dry sponge, may be collected, and its

quantity ascertained. This may be adduced as an example of the formation of water by combustion.

34. Take a small piece of pure potash, gently breathe on its surface, and place it on an insulated plate connected with the negative side of a powerful galvanic battery in a state of intense activity. Then bring a metallic wire from the positive side of the battery in contact with the upper surface of the alkali, and soon a very vivid action will be observed. Small globules, having a high metallic lustre, and of the appearance of quicksilver, will be seen, some of which will burn with explosion and a bright flame as soon as they are formed. Thus potash may be decomposed, and its metallic base rendered visible in a separate state.

35. Take the metallic substance formed in the last experiment, called potassium, make it very hot, and confine it in a small glass vessel of oxygen gas. Here a rapid combustion, with a brilliant white flame, will be produced, and the metallic globules will be converted into a white and solid mass, which will be found to be regenerated pure potash.

36. Place a small piece of potassium within a dry wine-glass, and in order to acquire an idea of its specific gravity pour a little alcohol, ether, or naphtha upon it; when, quitting the bottom of the glass, it will immediately rise to the surface of the liquid, it being, notwithstanding its metallic appearance, one of the lightest bodies known.

37. If a little potassium be dropped into a jar of chlorine gas, it burns spontaneously, and emits a bright red light. In this experiment a white salt is formed, muriate of potash.

38. If a globule of potassium be thrown upon water, it decomposes it with great violence: an instantaneous explosion is produced with brilliant flame, and a solution of pure potash is the result.

39. If a similar globule be placed upon ice, it will spontaneously burn with a bright flame, and perforate a deep hole in the ice, which will contain a solution of potash.

40. Take a piece of moistened turmeric paper, and drop a globule of potassium upon it. At the moment that it comes into contact with the water, it burns and moves rapidly upon

the paper, as if in search of moisture, leaving behind it a deep reddish brown trace.

41. When a globule of sodium is thrown into *hot* water, the decomposition of the water is so violent that small particles of the metal are thrown out of the water, and actually burn with scintillations and flame in passing through the atmosphere.

VII. EXPERIMENTS WITH THE EARTHS.

1. *Test for the presence of lime.*—Pour a little lime-water into a wine-glass, and put some solution of oxalate of ammonia, equally transparent, into another glass. If the two clear liquors be poured together, a white precipitate of oxalate of lime will immediately become visible.

Obs.—The oxalic has a greater affinity for lime than any other acid; and as it forms with it an insoluble substance, it is the most proper test for discovering this earth.

2. *To show the effects of carbonic acid upon lime.*—Pour a little lime-water into a phial, and throw some carbonic acid into it. The carbonic acid will seize the lime, and precipitate it in the state of carbonate of lime.

3. Take the phial made use of in the last experiment, with its contents, and convey an additional portion of carbonic acid into it. The carbonate of lime will now be re-dissolved, and the liquor rendered transparent.

Obs.—By these two last experiments, it appears that lime with a *small* quantity of carbonic acid is insoluble, and soluble with a larger quantity.

4. Take the transparent liquid produced in the last experiment (No. 3.) and give it heat. The earth will now be precipitated in the state of carbonate of lime, as before.

5. Pour some lime-water into a wine-glass, and a little solution of carbonate of potash into another glass. When these two transparent fluids are thrown together, an abundant precipitate of carbonate of lime will be the consequence.

5. Proceed as in the preceding experiment (No. 5.), but in-

stead of carbonate of potash pour a solution of Epsom salt into one of the glasses. When these transparent fluids are poured together, a mixed precipitate of carbonate of magnesia and sulphate of lime will be produced.

7. Take in the same manner, separately, lime-water and a solution of alum. The union of these solutions will produce a mixed precipitate of alumina and sulphate of lime.

8. *To produce a precipitate from two transparent fluids.*—If a strong solution of caustic potash and a saturated solution of Epsom salt be mixed, the union of these transparent fluids will produce also an abundant precipitate. But this will consist of magnesia and sulphate of potash.

9. *To detect carbonic acid.*—To a glass of water suspected to contain carbonic acid, add a small quantity of any of the other acids. If carbonic acid be present, it will become visible by a sparkling appearance on the sides of the glass and surface of the fluid.

10. Get two glasses of pure water, and into one of them pass a single drop of sulphuric acid, and mix it with the water. Pour a little muriate of barytes into the other glass, and no change will be perceived; pour some of the same solution into the first glass containing the sulphuric acid, and a white precipitate of sulphate of barytes will be produced.

Obs.—The most singular property of barytes is the tenacity with which it holds the sulphuric acid when combined with it. It has such an affinity for it, that it will not part with it even to pure alkalies. Hence pure barytes will decompose sulphate of potash or sulphate of soda.

11. *Test for lead.*—Prepare two glasses of water as before, conduct the experiment in the same way as the last, but instead of muriate of barytes use *nitrate of lead*. In this case sulphate of lead will be precipitated.

Obs.—Lead forms an insoluble compound with sulphuric acid, and hence the latter is sometimes used to detect the presence of this deleterious

metal; but the best test is a solution of sulphuretted hydrogen, or of some hydrosulphuret, *e. g.* To the suspected liquid add a little of this test, and if lead be present, it will give it a dark brown or blackish tinge. This test, however, is somewhat ambiguous, for it also blackens solutions of bismuth, silver, and some other metals.

12. Fill a glass tumbler half full of lime-water; then breathe into it frequently, at the same time stirring it with a piece of glass. The fluid which before was perfectly transparent, will presently become quite white, and if suffered to remain at rest, real chalk will be deposited.

Obs.—When intended for new experiments, pure lime should always be kept in well stopped bottles; for without this precaution, it would soon absorb carbonic acid, and become carbonate of lime. If lime-water be exposed to the air, it will soon be covered with a pellicle of carbonate of lime from the same cause. In like manner, if a little lime water be put into a glass syphon, and the legs of the syphon held upwards so as to enable a person to blow through it without the liquor running out, the breath will be found to give a milky colour to the lime-water, and carbonate of lime will be seen forming at the bottom of the liquor, which will effervesce with acids, and have every chemical quality that it had when in the quarry. This change is owing to the absorption of carbonic acid from the lungs—carbonate of lime being a compound of lime 28 and carbonic acid 22: its equivalent number therefore is 50.

VIII. EXPERIMENTS WITH THE METALS.

1. Prepare two glasses of rain-water, and into one of them drop a single drop of sulphuric acid. Pour a little *nitrate of*

silver into the other glass, and no change will be perceptible. Pour some of the same solution into the first glass, and a white precipitate of sulphate of silver will appear.

2. *To detect the presence of silver in solution.*—Prepare two glasses as in the last experiment, and into one of them put a drop or two of *muriatic acid*. Proceed as before, and a precipitate of muriate of silver will be produced.

Obs.—Silver has such an affinity for muriatic acid that the latter is employed as a test for detecting silver in solution.

3. Again take two glasses, as in experiment No. 1, and into one of them put a drop of sulphuric acid, and a drop or two of muriatic acid: proceed as before with the *nitrate of silver*, and a mixed precipitate will be produced, consisting of muriate of silver and sulphate of silver.

4. *To separate the metallic salts of silver whenever they occur in a state of mixture.*—Take a glass containing the mixed precipitate of the last experiment, and give it, by means of a lamp, the heat of boiling water. The sulphate of silver, if there be a sufficiency of water, will now be redissolved, and the muriate of silver will remain separate at the bottom of the vessel. By this method these metallic salts, whenever they occur in a state of mixture, may be separated.

5. *To produce a true muriate of lead.*—Mix one ounce of litharge of lead with one drachm of muriate of ammonia, in powder, and submit the mixture to a red heat in a clean tobacco-pipe. The increase of temperature will separate the ammonia in the form of gas, and the muriatic acid will combine with the lead. When the compound is well melted, pour it into a metallic cup, and you will have a true muriate of lead of a bright yellow colour, the brilliancy of which may be much heightened by grinding it as usual with oil. In this state it forms the colour called patent yellow.

Obs.—Muriate of lead, when fused in earthen crucibles, produces that useful pigment called Turner's yellow, or patent yellow, much used in

oil painting. The introduction of the artificial chrymate of lead, a yellow of much greater brilliancy, has lessened its consumption.

6. *Metallic revivification*.—Take one ounce of red lead, and half a drachm of charcoal, in powder, incorporate them well in a mortar, and then fill the bowl of a tobacco-pipe with the mixture. Submit it to an intense heat in a common fire, and when melted, pour it upon a slab. The result will be metallic lead completely revived.

7. Drop upon a clean plate of copper, a small quantity of solution of nitrate of silver; in a short time a metallic vegetation will be perceptible, branching out in very elegant and pleasing forms, furnishing an example of metallic revivification.

Obs.—Lead may be converted into an oxide by heating it in a situation where it can have free access to atmospheric air. All the oxides of lead may, however, be reduced to the metallic state by heating them with a mixture of tallow and charcoal, or any substance that will absorb the oxygen. This may readily be shown by placing a few grains of red lead upon a piece of charcoal, and fusing it with a blow-pipe. Even the oxide of lead, which is combined with flint glass, may be revived by melting the glass with any carbonaceous substance.

8. *Vitrification of Metals*.—Take a little red lead, expose it to an intense heat in a crucible, and pour it out when melted. The result will be metallic glass, and will furnish an example of the vitrification of metals.

9. Dissolve an ounce of acetate of lead in about a quart or more of water, and filter the solution. If this be put into a glass decanter, and a piece of zinc suspended in it by means of a brass wire, a decomposition of the salt will immediately commence, the lead will be set at liberty, and will attach itself to the remaining zinc, forming the metallic tree, which has been attributed to Dr. Black.

10. Procure a phial with a glass stopper accurately ground into it; introduce some copper wire, then entirely fill it with liquid ammonia, and stop the phial so as to exclude all atmospheric air. If left in this state, no solution of the copper will be effected. But if the bottle be afterwards left open for some time, and then stopped, the metal will dissolve and the solution will be colourless. Let the stopper be now taken out, and the fluid will become blue, beginning at the surface, and spreading gradually through the whole. If this blue solution has not been too long exposed to the air, and fresh copper filings be put in, again stopping the bottle, the fluid will once more be deprived of its colour, which it will recover only by the re-admission of air. These effects may thus be repeatedly produced.

11. *To effect the solution of a metal.*—Pour concentrated nitric acid upon pieces of iron, and very little action will be seen: but if a few drops of water be added, a most violent effervescence will immediately commence; the acid will be decomposed with rapidity, clouds of red nitrous gas will be evolved in abundance, and a perfect solution of the metal effected.

12. Take any solution of iron, a chalybeate water for instance, and add a small quantity of succinate of ammonia; in a little time a precipitate will be visible, being succinate of iron. By this test the quantity of iron in any solution may be accurately ascertained.

13. *Test for lead and other pernicious metals.*—In like manner add sulphuretted hydrogen to a solution of lead, and a deep brown precipitate will be occasioned.

14. *To precipitate one metal by means of another.*—Dissolve some quicksilver in nitrous acid, and drop a little of the solution upon a bright piece of copper. If it be then gently rubbed with a bit of cloth, the mercury will precipitate itself upon the copper, which will be completely silvered.

15. If a little nitro-muriate of gold be added to a fresh solution of muriate of tin, both being much diluted with water, the gold will be precipitated of a purple colour, forming that beautiful pigment called the purple precipitate of Cassius.

Obs.—Gold is also used in a state of solution, for staining ivory and ornamental feathers. It gives a beautiful and durable purple red; even marble may be stained with it. The nitro-muriatic acid is the menstruum used for this purpose. The potters dissolve gold in this way, to be applied to the common sort of porcelain. Bismuth or zinc will precipitate gold from this solution. Sulphuret of potash will likewise dissolve gold.

16. Take a phial with a solution of sulphate of zinc, and another containing a little liquid ammonia, both transparent fluids. By mixing them, a curious phenomenon may be perceived:—the zinc will be immediately precipitated in a white mass, and if then shaken, almost as instantly re-dissolved.

17. Add a colourless solution of galls to a solution of bismuth in nitric acid equally colourless, and a *brown* precipitate will be produced. This a distinguishing characteristic of this metal.

Obs.—Some of the French chemists recommend the use of the oxides of bismuth for dyeing, to fix some particular colours. It is said that pomatum, prepared with the oxide of bismuth, will turn the hair black.

18. *Tests for copper and arsenic.*—If a colourless solution of arsenic in caustic potash be poured into a colourless solution of copper, a *green* precipitate will be produced, forming an arseniate of copper similar to an ore found in the Cornish mines. These metals may be thus reciprocally detected.

Obs.—Roman vitriol, much used by dyers, and in many of the arts, is sulphate of copper. Fowling-pieces and tea-urns are browned by washing them with a solution of this salt. Verdigris is an acetate of copper. *Blue verditer*, much used for staining paper for hanging rooms, is a nitrate of copper combined with hydriate of lime. The beautiful grass-green colour of the

shops, called mineral green, is precipitated in a peculiar way from sulphate of copper, by means of caustic potash, and oxide of arsenic. The colour known by the name of Scheele's green is an arsenite of copper. The colour called *Brunswick green* is a triple salt, formed with potash, copper, and the tartaric acid.

19. *To shew the fixity of noble metals.*—Alloy a piece of silver with a portion of lead, place the alloy upon a piece of charcoal, attach a blow-pipe to a gasometer charged with oxygen gas, light the charcoal first with a bit of paper, and keep up the heat by pressing upon the machine. When the metals get into complete fusion, the lead will begin to burn, and very soon will be all dissipated in a white smoke, leaving the silver in a state of purity.

Obs.—Some solutions of the oxide of antimony are very powerful, and even poisonous when taken internally, unless in small doses.

20. If oxide of cobalt be dissolved in ammonia, a red solution will be produced, different in colour from that of all other metallic oxides.

Obs.—The oxide of cobalt forms the most perfect blue colour we are acquainted with.

21. If nickel be dissolved in nitric acid, a beautiful green solution will be formed. The oxide of this metal is used to give a delicate grass-green to porcelain, and like other metallic colours, bears the intense heat of their ovens without injury. A hyacinthine colour may be given to flint glass by melting it with this oxide.

22. If colourless prussiate of potash be added to a solution of titanium, this metal will be precipitated also of a green colour.

23. Add a little colourless solution of galls to a clear solution of antimony in nitro-muriatic acid, and the metal will be precipitated of a pale yellow colour. If oxide of antimony be

precipitated from nitro-muriatic acid, the precipitate will be white.

24. If a solution of tungstate of potash be poured into a solution of the green sulphate of iron, a yellow precipitate will fall down. By this experiment the distinguishing characteristic of this metal is exhibited.

25. If a solution of the green sulphate of iron be dropped into a nitro-muriate of gold, the last metal will be immediately precipitated. In this state it is often employed in gilding china.

26. If flowers, or any other figures, be drawn upon a riband or silk with a solution of nitrate of silver, and the silk, moistened with water, be then exposed to the action of hydrogen gas, the silver will be revived, and the figures, firmly fixed upon the silk, will become visible, and shine with metallic brilliancy.

Obs.—By proceeding in the same manner and using a solution of gold in nitro-muriatic acid, silks may be permanently gilt at a most trifling expense, and will exhibit an appearance the most beautiful that can be conceived.

27. To the same solution of gold add about a fourth part of ether; shake them together, and wait till the fluids separate; the upper stratum, or ethereal gold, is then to be carefully poured off into another vessel. If any polished steel instrument or utensil be dipped into this solution, and instantly plunged into water, the surface will have acquired a coat of pure gold.

Obs.—This is a very elegant and economical mode of preserving polished steel from rust.

28. If nitro-muriate of platinum be mixed with a fourth part of its bulk of ether, and the mixture suffered to settle, the ethereal solution of platinum may be decanted as in the preceding experiment. Polished brass, and some other metals immersed in this solution, will be covered with a coat of platinum. This process may be applied to many useful purposes.

Obs.—Mr. Strauss, after many experiments, it is said, succeeded in applying platinum to the coating of copper with as much ease as the common operation of tinning. The durability of this metal, and its resistance to acids and saline matters, must render this a most valuable discovery.

29. Prepare a very dilute and colourless solution of platinum by dropping a small quantity of the nitro-muriate of that metal into a glass of water. If a single drop of the solution of muriate of tin be added to this, a bright red precipitate will be instantly produced. A more delicate test than this of any metal cannot be conceived.

Obs.—This is the only means yet known to discover when gold has been alloyed with platinum.

30. If a morsel of the dried *crystals* of nitrate of silver (not the lunar caustic) be laid on a piece of burning charcoal, the metallic salt will immediately deflagrate, throw out the most beautiful scintillations that can be imagined, and the surface of the charcoal will be richly coated with metallic silver.

31. Add to a colourless solution of nitrate of mercury an equally colourless solution of sub-borate of soda. A double decomposition will be produced; and a bright yellow precipitate of borate of mercury formed: giving an instance of difference of colour in metals, by their union with different acids.

32. Into a diluted solution of sulphate of copper, pour a little liquid caustic ammonia. This will precipitate the copper of a blueish white. During its examination, however, the precipitate will be re-dissolved, and a beautiful blue liquid, called aqua celestis, will be the result.

33. *To shew that metals become insoluble the moment they impart their oxygen to foreign bodies.*—Dissolve a few crystals of nitro-muriate of gold in about eight times their weight of pure water; place a thin slip of charcoal in the solu-

tion, and heat the whole by means of a sand-bath. When the solution has acquired nearly a boiling heat, the gold will precipitate itself on the charcoal, in its metallic splendour, forming a singular and beautiful appearance.

34. *To illustrate the deoxidizing power of the sun's rays.*—Proceed as in the last experiment, and expose the vessel with its contents to the rays of the sun. Here the metal will be reduced, and the charcoal as effectually gilt as before.

35. Drop a little leaf-gold into nitro-muriatic acid, and it will instantly disappear.

Obs.—This experiment is designed to show the great solubility of the metals, when submitted to a proper menstruum. Gold has so little affinity for oxygen, that it cannot be easily oxidized, like the other metals; this, however, may be effected by amalgamating it with mercury, and applying heat, or by dissolving it in nitro-muriatic acid, and precipitating it with a solution of potash. See p. 139.

36. Pour a little purified nitric acid into one wine-glass, and muriatic acid into another; and drop a little leaf-gold into each. Here neither of these corrosive acids will act at all upon the metal, the gold will remain untouched. But let the whole contents of the two glasses be added together, the metal will disappear, and be as effectually dissolved as in the preceding experiment.

37. Mix a little metallic arsenic, in powder, with a few zinc filings, and then if treated with diluted sulphuric acid, arsenuretted hydrogen gas may be collected, which burns with a peculiar kind of lambent white flame.

38. If a portion of arsenuretted hydrogen gas, issuing from a very small tube, be set on fire, and then immersed in a large glass receiver of oxygen gas, and the stream of the gas kept up by the pressure of the bladder, a blue flame of uncommon splendour will be produced.

39. Take an amalgam of lead and mercury, and another

amalgam of bismuth, let these two solid amalgams be triturated, and they will instantly become fluid.

40. If a little pure white calomel be rubbed in a glass mortar with a little colourless solution of caustic ammonia, the whole will become intensely black.

41. On exposing a little of the solution of sulphate of manganese in a glass phial to the light of the sun, its rose colour will entirely fade. (This is another experiment to show the deoxidizing power of the sun's rays.) If the phial be removed into a dark room, the original colour of the solution will be restored.

42. If about a drachm of pulverized sulphate of copper be dissolved in a little boiling water, and an equal quantity of powdered muriate of ammonia in a separate vessel, in hot water, and the contents of the two glasses be mixed together, a quadruple salt will be formed, which gives a yellow colour to the solution while hot, and becomes green when cold.

43. Mix three grains of sulphur with nine grains of dry nitrate of silver, and lay the mixture in a small heap on an anvil, or on any piece of solid metal. If the mixture be now struck smartly with a *cold* hammer, the sulphur will inflame, but no detonation will ensue.

Obs.—This is an instance of a metallic salt being decomposed, and a combustible substance inflamed, by percussion.

44. If the experiment be repeated, and the mass be struck with a *hot* hammer, the mixture detonates, and the silver is reduced.

45. *Example of peculiar affinities.*—Pour a solution of nitrate of silver into a glass vessel, and immerse a few slips of copper in it. In a short time a portion of the copper will be dissolved, and all the silver precipitated in a metallic form. If the solution, which now contains copper, be decanted into another glass, and pieces of iron added to it, this metal will then be dissolved, and the copper precipitated.

46. Melt a portion of grain tin, and pour it into a metallic cup. Allow it to cool till it be congealed to some depth, then pierce the solid crust, and carefully pour out that portion which

is still liquid. If what remains in the vessel be suffered to cool entirely, it will present rhomboidal crystals of considerable size, formed by the assemblage of a great number of small needles longitudinally united. Treat silver in the same way, and you will procure a metallic mass crystallized in quadrangular octohedral prisms.

Obs.—These two last experiments will succeed better if the metal be poured into a vessel with an orifice in the bottom, which must be stopped with a proper plug, and this removed as soon as the upper crust hardens; the liquid metal will then run out, and that which is congealed will exhibit a regular crystallization.

48. *The tree of Diana.*—Make an amalgam with four parts of silver-leaf and two of mercury, and dissolve this amalgam in diluted nitric acid. Then add water to the solution, equal to 30 times the weight of the metals employed, and put the whole aside for use. If an ounce of this solution be at any time poured into a phial, and a small piece of soft amalgam of silver be dropped in, filaments of reduced silver will shoot from it, and extend upwards in the form of a shrub.

49. If two parts of sulphate of copper, and three of carbonate of ammonia (the one a blue, and the other a white salt), be rubbed together in a glass mortar till the carbonic acid be expelled, the mass will become soft and humid, and, when dried, form a crystalline powder of a most beautiful deep violet colour.

Obs.—This compound was formerly called *cuprum ammoniacum*.

50. If a little colourless and recently prepared muriate of tin be poured into a rich green solution of muriate of copper, the copper will be deprived of a portion of its oxygen, and a white muriate of copper precipitated.

51. Into the phial containing the white muriate of the last experiment, pour a little muriatic acid. The precipitate will quickly be dissolved, and the solution will be colourless.

52. Procure some solution of sulphate of iron at the *minimum* of oxidizement, by digesting iron filings with the common sulphate. Into this, when filtered, drop a little of the solution of prussiate of potash, and a white prussiate of iron will be precipitated.

53. If a very little colourless nitric acid be added to a solution of sulphate of iron, prepared as in the last experiment, the addition of the prussiate of potash will produce not the white, but the blue prussiate of iron.

54. Pour pure nitric acid on the black oxide of manganese, and no solution will be effected. But if a little sugar be added, the sugar will abstract a part of the oxygen from the nitric acid, and then the acid will be enabled to dissolve the metal.

55. Expose an ounce of nitric acid for an hour, in an open phial, to the direct rays of the sun, and pour another ounce of the same acid, that has not been so exposed, into another phial. If a little of the black oxide of manganese be now put into each, the oxide in the *first phial* will be dissolved, while that in the *other* will not be affected by the acid.

56. If a piece of bright silver be dipped in a solution of sulphate of copper, it will come out unchanged: but if the blade of a clean pen-knife, or any piece of *polished iron*, be dipped in the same solution, the iron will instantly put on the appearance of copper.

57. Take the piece of silver employed in the last experiment, hold it *in contact with the iron*, and then, in this situation, dip them into the same solution, and both will be covered with copper.

58. Dissolve some oxide of nickel in caustic ammonia, which will produce a solution of a rich blue colour. By exposure to the air this gradually changes to a purple, and lastly to a violet. The addition of an acid will, however, convert the whole to a green.

59. With the green solution of the last experiment, pour caustic ammonia upon it. The original blue colour will now be reproduced.

60. Prepare a colourless solution of tartrate of potash and antimony (the common emetic tartar), and pour into it a little

liquid sulphuretted hydrogen. This will combine with the metallic oxide, and form an orange-coloured precipitate.

61. Melt together equal parts of copper and antimony, the one a yellow, the other a white metal, and the alloy that results from this mixture will take the colour of the violet.

62. If the gray sulphuretted oxide of antimony be fused in a crucible, a beautiful transparent glass is procured, which is called the *glass of antimony*. N. B.—This takes the colour of the hyacinth.

63. Dissolve dry nitrate of silver in pure water; add a little oil of turpentine, shake the mixture, and cork it close. Submit the phial with its contents to the heat of boiling water for an hour, when the metal will be revived, and the inside of the phial, where the oil reposed on the aqueous solution, will be beautifully silvered, the revived metal forming a metallic ring extending quite round the phial.

64. Dip a slip of white silk in a solution of nitro-muriate of gold in distilled water, and dry it in the air. Silk thus prepared will not be altered by hydrogen gas: but if another piece of silk be dipped in the solution, and exposed while *wet* to the same current of hydrogen gas, instant signs of metallic reduction will appear; the colour will change from yellow to green, and a brilliant film of reduced gold will soon glitter on its surface.

65. If a piece of silk be immersed in a solution of nitrate of silver, and dried in a dark place, and then submitted to hydrogen gas, the silver will not be reduced; but if exposed while *wet* to a stream of the same gas, the surface will quickly be coated with reduced silver: various colours, such as blue, purple, red, orange, and yellow, will accompany the reduction and the threads of the silk will look like silver wire.

Obs.—During these experiments, the silk should be constantly kept wet with distilled water.

66. *To produce a variety of beautiful colours.*—Dissolve some crystals of muriate of tin in distilled water, then dip a piece of white silk in the solution, and dry it in the air. If this be now immersed in hydrogen gas, no change will be ob-

served; but if it be exposed while *wet* to the same current of gas, the reduction will soon commence, attended with a great variety of beautiful colours, as red, yellow, orange, green and blue, variously intermixed.

67. Prepare a strong solution of phosphorus in sulphuric ether, and dip a piece of white silk in the solution; then, when the ether has evaporated, and the phosphorus begins to fume, apply a solution of nitro-muriate of gold, made by dissolving the crystals of that salt in distilled water; the silk will in an instant be covered with a splendid coat of metallic gold.

68. Proceed as in the last experiment, and instead of the solution of gold, apply, with a camel's-hair pencil, a solution of nitrate of silver. Here the silver will instantly be restored to its metallic brilliancy, and frequently attended by spangles of a beautiful blue.

69. If a bit of white silk be immersed in an ethereal solution of gold, and dried, the application of phosphorized ether will only impart a brown colour to the silk; but if, as soon as the phosphorus begins to fume, it be placed on the palm of the hand, and breathed on for a considerable time, the brown will be succeeded by a purple tinge, and the metallic lustre of the gold will soon begin to appear.

70. "An aqueous solution of nitro-muriate of gold," says Mrs. Fulhame, "was poured into a china cup containing some phosphorized ether; instantly the gold began to assume its metallic splendour, attended with a variety of colours, as purple, blue, and red, the beauty of which cannot be described; but which depends on the different degrees of the reduction."

71. With a needle pass a thread through a small bit of phosphorus, previously freed from moisture by immersing it in alcohol. If this be suspended in an aqueous solution of nitro-muriate of gold, in a few minutes the phosphorus will become covered with pure gold.

72. If a piece of white silk be dipped in an aqueous solution of nitro-muriate of gold, and exposed while wet to sulphurous acid gas, the whole piece will in a few seconds be covered with a coat of reduced gold, which remains permanent.

73. If a piece of white silk be immersed in an aqueous solu-

tion of nitrate of silver, thoroughly dried in the dark, and then exposed to sulphurous acid vapours, it will suffer no change; nor, if it be wetted with *alcohol* and then replaced in the vapour, will any sign of reduction appear; but if it be wetted with pure *water*, and then exposed to the vapour, metallic silver will immediately be seen on its surface.

Obs.—To perform these experiments, a glass funnel is a convenient apparatus. The silk may be suspended by a thread passed through it, and made fast to the funnel with a cork. The funnel is then to be placed on a table, and by moving it a little over the edge of the table, a lighted match may be readily introduced, and when the glass is full of vapour, the match may be withdrawn. The vapour is confined by sliding the funnel back upon the table; and thus the phenomena of the experiment may be easily observed.

EXPERIMENTS TO RE-PRODUCE METALS.

(*a.*) Dip a piece of white calico in an aqueous solution of acetate of lead, and then drop a little solution of sulphuret of potash upon it. If this be now placed in the palm of the hand, the lead will be observed gradually to revive, and will soon be reduced to its metallic state.

(*b.*) Dissolve some sulphuret of potash in alcohol, and immerse a slip of white silk in the solution. If a drop of an aqueous solution of sulphate of manganese be now applied, films of metallic manganese, bright as silver, will instantly appear.

(*c.*) If a bit of silk be immersed in diluted acetate of lead, and exposed while *wet* to a stream of sulphuretted hydrogen gas, a brown tinge will instantly diffuse itself, like a passing shadow, over the whole surface of the silk, accompanied with a bright coat of reduced lead, resembling silver.

(*d.*) If a piece of silk be immersed in an aqueous solution of muriate of tin, and exposed while *wet* to a stream of the same

gas, reduced tin of great brightness will immediately cover the surface, and in a little time this will be accompanied by various colours, such as blue, orange and purple.

(c.) A piece of silk treated in the same way, but dipped in an aqueous solution of muriate of arsenic, will be covered with resplendent metallic arsenic, attended with a citron yellow colour.

(f.) Prepare two glasses of very dilute nitrate of copper; into one drop a little liquid ammonia, and into the other some diluted arseniate of potash. The addition of these two *coloursless* solutions will produce very different effects; for the one glass will have an abundant precipitate of a brilliant sapphire blue, and the other a precipitate of a beautiful grass green.

SYMPATHETIC INKS.

1. Write upon paper with a diluted solution of muriate of copper, when dry it will not be visible, but, on being warmed before the fire, the writing will become of a beautiful yellow.

2. Write with a solution of muriate of cobalt, and the writing, while dry, will not be perceptible; but if held towards the fire, it will then gradually become visible; and if the muriate of cobalt be made in the usual way, the letters will appear of an elegant green colour.

3. Write with acetate of cobalt, or with a muriate of cobalt, previously purified from the iron which it generally contains. When the writing is become dry, these letters will also be invisible. Warm the paper a little, and the writing will be restored to a beautiful blue.

4. Draw a landscape with Indian ink, and paint the foliage of the vegetables with muriate of cobalt, the same as that used in Experiment No. 2., and some of the flowers with acetate of cobalt; and others with muriate of copper. While this picture is cold it will appear to be merely an outline of a landscape, or winter scene; but when gently warmed, the trees and flowers will be displayed in their natural colours, which they will preserve only while they continue warm. This may be often repeated.

Obs.—The acetate of cobalt is always of a red colour in the cold solution, but as a sympathetic ink, when warmed, it is a fine blue.

5. Write with a dilute of nitrate of silver, which, when dry, will be entirely invisible; hold the paper over a vessel containing sulphate of ammonia, and the writing will appear very distinct. The letters will shine with the metallic brilliancy of silver.

6. Write with a solution of nitrate or acetate of lead. When the writing is dry it will be invisible. Then having prepared a glass decanter with a little sulphuret of iron strewed over the bottom of it, pour a little very dilute sulphuric acid upon the sulphuret, so as not to wet the mouth of the decanter, and suspend the writing, by means of the glass stopper, within the decanter. By an attention to the paper the writing will become visible by degrees, as the gas rises from the bottom of the vessel.

7. Write with a weak solution of sulphate of iron, let it dry, and it will be invisible. By dipping a feather in tincture of galls, and drawing the wet feather over the letters, the writing will be restored and appear black.

8. Write with a similar solution, and when dry, wash the letters in the same way with prussiate of potash, and they will be restored of a beautiful blue.

9. Write with a solution of sulphate of copper, wash as before with prussiate of potash, and the writing will be revived of a reddish brown colour.

10. Write on paper with a solution of nitrate of bismuth; when this is dry the writing will be invisible; but if the paper be exposed to sulphuretted hydrogen gas, the words will be distinctly legible.

11. A letter written with a diluted solution of bismuth becomes, when dry, illegible; but a feather dipped in a solution of sulphuret of potash will instantly blacken the oxide, and revive the writing.

MISCELLANEOUS EXPERIMENTS.

1. Take a slip of blue litmus paper, dip it into acetic acid, and it will immediately become red. This is a test to delicate,

that, according to Bergman, it will detect the presence of sulphuric acid, even if the water contain only one part of acid to thirty-five thousand parts of water. Litmus paper, which has been thus changed by immersion in acids, is, when dried, a good test for the alkalies; for if it be dipped in a fluid containing the smallest portion of alkali, the red will disappear, and the paper be restored to its original blue colour.

2. Take a slip of turmeric paper, and dip it into any alkaline solution; this will change the yellow to a deep brown. In many cases turmeric is preferable to litmus paper for detecting alkali in solution, as it suffers no change from carbonate of lime, which is often found in mineral waters. This paper will detect the presence of soda, though it should amount to no more than $\frac{1}{1000}$ th part of the water.

Obs.—The paper thus changed by an alkali, would, if dried, be still useful as a test for acids, as these restore its original yellow.

3. *Sublimation.*—Into a large glass jar, inverted upon a flat brick tile, and containing near its top a branch of fresh rosemary, or any other such shrub, moistened with water, introduce a flat thick piece of heated iron, on which place some gum benzoin in gross powder. The benzoic acid, in consequence of the heat, will be separated, and ascend in white fumes, which will at length condense, and form a most beautiful appearance upon the leaves of the vegetable. This will serve as an instance of sublimation.

4. Introduce a little carbonate of ammonia into a Florence flask, and place that part of the flask which contains the salt on the surface of a bason of boiling water: the heat will soon cause the carbonate of ammonia to rise undecomposed, and attach itself to the upper part of the vessel, exhibiting another example of simple sublimation.

5. Mix a little acetate of lead with an equal portion of sulphate of zinc, both in fine powder; stir them together with a piece of glass or wood, and no chemical change will be perceptible: but if they be rubbed together in a mortar, the two

solids will operate upon each other; an intimate union will take place, and a fluid will be produced.

Obs.—If alum or Glauber salt be used instead of sulphate of zinc, the experiment will be equally successful.

6. Pour a little water into a phial containing about an ounce of olive oil. Shake the phial, and if the contents be observed, we shall find that no union has taken place. But if some solution of caustic potash be added, and the phial be then shaken, an intimate combination of the materials will be formed by the disposing affinity of the alkali, and a perfect soap produced.

7. Put a little common sulphur into one-eighth of its weight of nitre, into an iron dish, place it under a jar of oxygen gas, and set fire to it by means of a red hot iron, and sulphuric acid will be formed. This is an example of the formation of an acid by combustion.

8. Take the acid formed in the last experiment, concentrate it by boiling, mix it with a little powdered charcoal, and submit the mixture in a Florence flask to the heat of an Argand's lamp. By this process sulphur will be regenerated, and will sublime into the neck of the flask. An instance of the decomposition of an acid.

9. Melt sulphur in a small iron ladle, and carry it into a dark room in a state of fusion. If one ounce or two of copper filings be now thrown in, light will be evolved.

10. Fuse a small quantity of nitre in a crucible, and, when in complete fusion, throw pulverized coal into it by small quantities at a time. The carbonaceous matter will decompose the nitre, and the bituminous part will burn away without acting upon it.

Obs.—This experiment will show the mode of analysing coal; for every 100 grains of nitre decomposed in this way, denote ten grains of carbon.

11. If hot water be poured into a glass jar of cold water,

it will remain on the *surface*; but if cold water be poured upon hot water, it will sink to the *bottom* of the vessel. . . This experiment may be rendered more obvious by colouring that portion of the water which is poured in.

Obs.—The object of this experiment is to show the change of the specific gravity of the *same* body, merely by the agency of caloric.

12. Into a glass of water containing a small portion of common salt, drop some of the clear solution of nitrate of silver, and an insoluble precipitate of muriate of silver will be produced.

Obs.—This experiment is intended to give the pupil some idea of the method of analysing mineral waters. Every 100 grains of this precipitate, when dried, indicate 42 grains of common salt.

13. Into a glass of Aix-la-Chapelle water, or water holding a small portion of potash, drop a little of the solution of nitromuriate of platinum, and an immediate yellow precipitate will be produced.

Obs.—This is another instance of the nature of the means usually employed to detect whatever substances may be dissolved in mineral waters.

14. Into distilled water drop a little spirituous solution of soap, and no chemical effect will be perceived; but if some of the same solution be added to hard water, a milkiness will be immediately produced, more or less, according to the degree of its impurity.

Obs.—This a good method of ascertaining the comparative purity of spring water.

TABLE OF WEIGHTS AND MEASURES.

New French Weights and Measures (computed by DR. URE.)

1.—*Measures of Length: the Metre being at 22°, and the
Foot at 62°.*

	English inches.				
Millimetre	=	0.03937			
Centimetre	=	0.39371			
Decimetre	=	3.93708			
Metre *	=	39.37079	Mill.	Fur.	Yds. Feet. In.
Decametre	=	393.70790	=	0 0	10 2 9.7
Hecatometre	=	3937.07900	=	0 0	109 1 1.078
Kilometre	=	39370.79000	=	0 4	213 1 10.3
Myriometre	=	393707.90000	=	6 1	156 0 9.17

2.—*Measures of Capacity: Cubic inch contains 252.5 Imperial
grains of water, at 62°.*

		Cubic inches.		
Millilitre	=	0.06112		
Centilitre	=	0.61120		
Decilitre	=	6.11208		<i>Imperial.</i>
Litre	=	61.12079	=	Gallons. Pints.
Decalitre	=	611.20792	=	0 1.76377
Hecatolitre	=	6112.07920	=	2 1.4464
Kilolitre	=	61120.79208	=	22 0.2640
Myriolitre	=	611207.92080	=	220.47
				2204.71

* Recently determined by Captain Kater to be 39.37079 inches.
(Phil. Trans. 1818, p. 109).

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3.—Measures of Weight.

	English grains.	
Milligramme =	0154	
Centigramme =	1543	
Decigramme =	15433	Avoirdupois.
Gramme =	154330	Pound.
Decagramme =	1543300 =	0.022
Hectogramme =	15433000 =	0.220
Kilogramme =	154330000 =	2.204
Myriogramme =	1543300000 =	22.047

Correspondence of English Weights and Measures with those used in France before the Revolution.

§ 1.—Weights.

The Paris pound, *poids de marc* of Charlemagne, contains 9216 Paris grains; it is divided into 16 ounces, each ounce into 8 gros, and each gros into 72 grains. It is equal to 7561 English troy grains.

The English troy pound of 12 ounces contains 5760 English troy grains, and is equal to 7021 Paris grains.

The English avoirdupois pound of 16 ounces contains 7000 English troy grains, and is equal to 8532.5 Paris grains.

To reduce

Paris grains to English troy grains, divide by } 1.2189
English troy grains to Paris grains, multiply by }

To reduce

Paris ounces to English troy, divide by }
English troy ounces to Paris, multiply by } 1.015734

§ 2.—Long and Cubical Measures.

To reduce

Paris running feet, or inches, into English, multiply by }
English running feet, or inches, into Paris, divide by } 1.065977

To reduce

Paris cubic feet, or inches, to English, multiply by }
English cubic feet, or inches, to Paris, divide by } 1.211278

TABLE OF WEIGHTS AND MEASURES. 299

Correspondence between English and other Foreign Weights and Measures.

I.—English Weights and Measures.

Troy Weight.

Pound.	Ounces.	Drms.	Scruples.	Grains.	Grammes.
1	= 12	= 96	= 288	= 5760	= 372.96
	1	= 8	= 24	= 480	= 31.08
		1	= 3	= 60	= 3.886
			1	= 20	= 1.295
				1	= 0.6476

Avoirdupois Weight.

Pound.	Ounces.	Drms.	Grains.	Grammes.
1	= 16	= 256	= 7000	= 453.25
	1	= 16	= 437.5	= 28.328
		1	= 27.34375	= 1.7705

Measures.

Gal.	Pints.	Ounces.	Drms.	Cubic Inch.	Litres.
1	= 8	= 128	= 1024	=	= 3.78515
	1	= 16	= 128	= 28.875	= 0.47398
		1	= 8	= 1.8047	= 0.02957
			1	= 0.2256	= 0.00396

N. B.—The English ale gallon contains 282 cubical inches.

The wine gallon contains 58176 Troy grains; and the wine pint 7272 Troy grains.

II.—German.

71lbs. or grs. English troy	=	74lbs. or grs. Germ. apoth. wt.
1 oz. Nuremberg, medic. weight	=	7 dr. 2 sc. 9 gr. English.
1 mark Cologne	=	7 oz. 2 dwt. 4 gr. English troy.

III.—Dutch.

1 lb. Dutch	=	1lb. 3 oz. 16 dwt. 7 gr. English troy
787½lbs. Dutch	=	1038lbs. English troy.

IV.—Swedish Weights and Measures, used by Bergmann and Scheele.

The Swedish pound, which is divided like the English apothecary, or troy pound, weighs 6556 grs. troy.

The kanne of pure water, according to Bergmann, weighs 42250 Swedish grains, and occupies 100 Swedish cubical inches. Hence the kanne of pure water weighs 48088.719444 English troy grains, or is equal to 189.9413 English cubic inches; and the Swedish longitudinal inch is equal to 1.238435 English longitudinal inches.

300 TABLE OF WEIGHTS AND MEASURES.

By Everard's experiment, and the proportions of the English and French foot, as established by the Royal Society and French Academy of Sciences, the following numbers are ascertained :

Paris grains in a Paris cubic foot of water at 56° F.	= 645511
English grains in a Paris cube foot of water .	= 529922
Paris grains in an English cube foot of water .	= 533247
English grains in an English cube foot of water	= 437489.4
English grains in an English cube inch of water	= 253.175

As a cubic foot of water weighs very nearly 1000 ounces avoirdupois, the specific gravities of bodies express the ounces in a cubic foot of them, the density of water being called 1000.

A GLOSSARY

OF

CHEMICAL TERMS.

Absorption. The passage of a gas, or vapour, into a liquid or solid substance; or of a liquid into the pores of a solid.

Obs.—If muriatic acid gas be thrown into water, the water becomes acidulous, and absorption of the gas is said to have taken place. When a gas loses its gaseous properties by combination, it is said to be absorbed; but this term is not employed, when speaking only of the condensation of a gas by cold or pressure.

Acetometer. An instrument for measuring the strength of vinegar.

Acrescent. Substances which become sour spontaneously, or vegetable and animal juices.

Accension. A term employed by the old chemists to denote sudden inflammation or conflagration, by the mixture of two or more substances.

Acetates. Salts formed by the combination of acetic acid with alkalies, earth and metallic oxides.

Acidifiable. Capable of forming an acid. Thus sulphur is said to be an acidifiable base.

Acids. The most important class of chemical compounds. See page 81.

Acidules. A term applied to the natural combination of some acids with a portion of potash. The oxalic acid and the tartaric are the only acids that have hitherto been found in this state of semi-saturation.

Adopter. A chemical utensil fixed between the head of a still and its receiver. Thus a tube fixed on the head of a retort for the purpose of lengthening it, is called an adapter, and sometimes an adopter. A vessel having two necks when used for a similar purpose bears the same name.

Aeriform Fluids. Fluid substances combined with an additional portion of Caloric sufficient to give them the gaseous form. See *Gases*.

Affinity, Chemical. A term used to express that peculiar propensity which different species of matter have to unite with each other, or with portions of matter of their own species. See Chap. xxi. page 157.

— *of Aggregation.* A force by which two bodies of the same kind tend to combine, and by which an aggregate is formed without the chemical properties of the substances being all changed.

— *of Composition.* The force by which substances of different kinds unite, and by which matter is formed whose properties are different from those of the bodies before their combination. This attraction is stronger in proportion as the nature of the bodies is different between which it is exerted.

Agent. Any substance having the property of producing chemical action is called a chemical agent.

Aggregates. Substances whose parts are united by cohesive, and not by chemical attraction. See *Affinity of Aggregation*, page 157.

Albumen. The modern name for coagulable lymph; or that peculiar animal substance which forms the serum of the blood, the white of eggs, and other compounds.

Alcohol. Rectified spirit of wine. When good, its specific gravity is only 0.836.

Alcemic. A term formerly given to several stills used by chemists for their distillations.

Alkalies. The pretended universal solvent of the ancient chemists.

Alkaliescent. Any substance in which alkaline properties are beginning to be developed, or to predominate, is termed alkaliescent.

Alkalies. Peculiar substances which have a burning and caustic taste, and a strong tendency to combination. When united with acids, they form mild alkaline salts. See page 65.

Alloys. A combination of any two metals, except mercury, is called an alloy: *e. g.* gold is alloyed either with silver or copper, for the purposes of coinage. See page 151.

Alluvial. Alluvial formations, in geology, are recent deposits in valleys or in plains, of the *detritus* of the neighbouring mountains. Alluvial depositions are composed of gravel, loam, clay, sand, brown coal, wood coal, bog iron ore, and calc tuff.

Aluminium. The pure base of alumina, which is thought to be of a metallic nature.

Amalgam. A combination or mixture of mercury with any other metals, is called an amalgam. See page 153.

Ammoniacal Salts. Salts formed by the union of an acid with ammonia, or volatile alkali.

Analysis. The resolution of a substance into its constituent parts, for the purpose of examination. See page 7.

Annealing. The art of rendering substances tough which are naturally hard and brittle: *e. g.* glass and iron are annealed by gradual cooling; brass and copper by heating, and then suddenly plunging them in cold water.

Apparatus, Chemical. All the utensils made use of in a chemical laboratory; the principal of which consist of stills, furnaces, crucibles, retorts, receivers, matrasses, worm-tubs, pneumatic troughs, thermometers, &c. See *Plates*.

Apyrous. Bodies which sustain the action of heat for a considerable time, without change of figure or other properties, have been designated by this term.

Arcanum Duplicatum. The old name for what is now called sulphate of potash.

Areometer. A graduated glass instrument with a bulb, by which the specific gravity of liquids is ascertained.

Argil. The old name for alumina, or common clay.

Argillaceous. A term applied to those earths which contain alumina or clay.

Aroma. A term used for the odour which arises from certain vegetables, or their infusions.

Arsenate. A salt formed by the combination of any base with the arsenic acid.

Ashes. The fixed residue of combustible substances, which remains after being burnt, is called ashes. In chemistry it is most commonly used to denote the residue of vegetable combustion.

Assay. The operation of determining the quantity of valuable or precious metal contained in any mineral or metallic mixture, by analysing a small part thereof.

Atmometer. An instrument contrived by Professor Leslie for measuring the quantity of exhalation from a humid surface in a given time.

Atmospheres. This term is used to express the degree of additional pressure given to fluids. Thus, if, in order to impregnate water with any of the gases, I give it a pressure of 15lbs. upon every square inch of surface, I am said to give it *one* atmosphere; if 30lbs. *two* atmospheres, &c. See page 12.

Attraction. Chemical attraction is a term synonymous with *affinity*. See page 157.

Azote. A name given by the French chemists to *nitrogen*.

Balance. A lever, the axis of motion of which is formed with an edge like that of a knife; and the two dishes at its extremities are hung upon edges of the same kind. See fig.

Obs.—The beginning and end of all chemical processes consist in weighing.

Balloon. A term given by the French to their spherical chemical receivers.

Balsams. Certain aromatic resinous substances, which are obtained from some trees by incisions. Of this kind are the Canada balsam, the balsam of Copaiva, the balsam of Tolu, &c.

Barytes. The base of the earth called barytes.

Bewometer. An instrument which shows the variation of the pressure of the atmosphere, by the rise or fall of a column of mercury in a glass tube attached to a graduated plate.

Base or Bases. A chemical term usually applied to earths, alkalis or the metal, which is combined with an acid to form a salt.

Baths. Vessels for distillation or digestion, contrived to transmit heat gradually and regularly.

Baths, Sand. Vessels filled in part with dry sand, in which retorts are placed which require a greater heat than can be given by boiling water. They are often called *sand-heads*.

Water. Vessels of boiling water, in which other vessels containing the matters to be distilled or digested are placed in order that the same heat may be kept up throughout the whole of any particular process.

Obs.—A considerable greater heat may be given to the water bath by dissolving various salts in it. Thus a saturated solution of common salt boils at 225° . $3'$, or 13° $2'$ Fahr. above the boiling point of water. By using solution of muriate of lime, a bath of any temperature from 212° to 252° , may be conveniently obtained.

Benzoates. Salts formed by the combination of any base with the benzoic acid.

Bitters. The mother-liquor remaining after the crystallization of sea salt. It generally contains sulphate of magnesia, and a small portion of sulphate of soda.

Bitumens. A generic term, applied to a variety of fossil inflammable substances.

Blow-Pipe. An instrument to increase and direct the flame of a lamp or candle for the analysis of minerals, and for other chemical purposes.

Bell-Head. A round chemical vessel with a long neck, usually employed for digestions. It is also called a *matras*. See fig. 12, pl. I.

Borates. Salts formed by the combination of any base with the acid of borax.

Boron. The undecomposable base of boracic acid.

Button. A name given to the small round piece of metal which is found at the bottom of a crucible after a metallic ore or an oxide of metal has been reduced.

Calcareous. This term is applied to describe chalk, marble, and all other combinations of lime with carbonic acid.

Calcination. The application of heat to saline, metallic, or other

substances; so regulated as to deprive them of moisture, &c., and yet preserve them in a pulverulent form.

Caloric. The chemical term for the matter of heat.

—, *Free*, is caloric in a separate state, or if attached to other substances, not *chemically* united with them. See page 18.

—, *Latent*, is the term made use of to express that portion of caloric which is chemically united to any substance so as to become a *part* of the said substance. See page 18.

Calorimeter. An instrument for ascertaining the quantity of caloric disengaged from any substance that may be the object of experiment.

Calx. A term formerly used to describe a metallic oxide.

Camphorates. Salts formed by the combination of any base with the camphoric acid.

Capillary. A term usually applied to the rise of the sap in vegetables, or the rise of any fluid in very small tubes; owing to a peculiar kind of attraction, called capillary attraction.

Capsules. Small saucers of clay for roasting samples of ores, and for smelting them to ascertain their value.

Caput Mortuum. A term signifying *dead-head*, being that substance which remains in a retort after distillation to dryness. See *Residuum*, which is the modern term.

Carbon. The basis of charcoal. See page 180.

Carbonates. Salts formed by the combination of any base with carbonic acid. See page 122.

Carburets. Compound substances, of which carbon forms one of the constituent parts. Thus plumbago, which is composed of carbon and iron, is called carburet of iron. See page 248.

Case-hardening. A process by which certain metallic articles are made to possess all the hardness of steel with the toughness of iron.

Carot. A term used by miners to distinguish the opaque specimens of sulphate of barytes.

Causticity. That quality in certain substances by which they burn or corrode animal bodies to which they are applied. It is best explained by the doctrine of chemical affinity. See page 165.

Cement. Whatever is employed to unite or cement things together of the same or different kinds, may be called a cement. In which sense it includes lutes, glues, and solders of every kind.

Cementation. A process by which metals are purified or changed in their qualities by heat without fusion, by means of a composition called a cement, with which they are covered. Thus, iron by being kept a long time in a certain degree of heat, surrounded by charcoal powder, is converted into steel.

- Chalybeate.** A term descriptive of those mineral waters which are impregnated with iron. See *Martial*.
- Charcoal.** Wood burnt in close vessels: it is an oxide of carbon; and generally contains a small portion of salts and earth. Its carbonaceous matter may be converted by combustion into carbonic acid gas. See page 181.
- Chatoyant.** A term much used by the French chemists to describe a property in some metallic and other substances of varying their colours according to the way in which they are held; as is the case with the feathers of some birds, which appear very different when seen in different positions.
- Chert.** A term made use of in describing a species of siliceous stones, which are coarser and softer than common flint. It is often found in large masses in quarries of limestone.
- Chlorides.** Compound bodies formed by the chemical union of any substance with chlorine.
- Chlorine.** A name given to the substance formerly called oxy-muriatic acid. See page 191.
- Chromates.** Salts formed by the combination of any base with the chromic acid.
- Citrates.** Salts formed by the combination of any base with citric acid.
- Coal.** A term applied to the residuum of any dry distillation of animal or vegetable matter.
- Cohesion.** A force inherent in all the particles of all substances, excepting light and caloric, which prevents bodies from falling in pieces. See *Affinity*.
- Cohobation.** When a distilled fluid is poured again upon the matter from which it was distilled, in order to make it stronger, it is called cohobation. It is not much practised by modern chemists.
- Columbates.** Salts formed by the combination of any base with the columbic acid.
- Combination.** A term expressive of the intimate union of two or more substances; in opposition to mere mechanical mixture.
- Combustibles.** Substances capable of combining more or less rapidly with oxygen. They are divided by chemists into simple and compound combustibles.
- Combustion.** The act of absorption of oxygen by combustible bodies from atmospheric or vital air.
- Comminution.** The reduction of hard bodies into small particles. By this process the heaviest substances may be made to float in the lightest fluids.
- Concentration.** The act of increasing the specific gravity of bodies. The term is usually applied to fluids which are rendered stronger by evaporating a portion of the water which they contain.

Concretions (*Morbid*). Solid deposits, formed by disease in the soft parts, or in the cavities of animal bodies.

Condensation. The act of bringing the component parts of vapour, or gas, nearer together by pressure, or by cold. Thus atmospheric air may be condensed by pressure, and aqueous vapour by the subtraction of caloric, till it is converted into water.

Congelation. The act of freezing.

Crucibles. Vessels used in chemistry in the various operations of fusion by heat. They are made of baked earth, or metal, in the form of an inverted cone. See fig. 14, 15, 16, 17, plate II.

Crystallization. An operation of nature in which various earths, salts, and metallic substances, pass from a fluid to a solid state, assuming certain determinate geometrical figures.

Crystallization, *Water of*. The portion which is combined with salts in the act of crystallizing, and becomes a *component* part of the said saline substances.

Cupel. A vessel made of calcined bones, mixed with a small proportion of clay and water. It is used whenever gold and silver are refined by melting them with lead. The process is called cupellation.

Decombustion. Synonymous with *Deoxidizement*; which see.

Decomposition. The separation of the constituent principles of compound bodies by chemical means.

Decrepitation. The sudden decomposition of salts attended with a crackling noise whenever such salts are thrown into a red-hot crucible, or upon an open fire.

Deflagration. The vivid combustion produced whenever nitre, mixed with an inflammable substance, is exposed to a red heat.

Deliquescence. Becoming moist, or liquid, by means of water which they absorb from the atmosphere, in consequence of the great attraction of saline bodies for that fluid.

Deliquium, is the state of potash, or any deliquescent salt, when it has so far deliquesced by exposure to the air as to have become a liquid.

Delite. A term used by some of the French writers, signifying to break by the action of the air, like a soft stone into layers. See *Annales de Chimie*, tome xix. page 79.

Deoxidize. To deprive a body of oxygen.

Deoxidizement. A term made use of to express that operation by which one substance deprives another substance of its oxygen.

Dephlegmation. The act of separating the water from chemical liquors.

Depuration. The purging or separating any liquid in a state of purity from its fæces or lees.

Detonation. A species of explosion commonly applied to that of

ashes when thrown upon burning charcoal. See *Experiment*.

Digestion. The effect produced by the continued soaking of a solid substance in a liquid, with the application of heat.

Digester, Papin's. An apparatus for reducing expeditiously animal or vegetable substances to a pulp or jelly.

Distillation. A process for separating the volatile parts of a substance from the more fixed, and preserving them both in a state of separation.

Docimastic Art. The art of assaying metals.

Ductility. A quality of certain bodies, in consequence of which they may be drawn out to a certain length without fracture. See gold, page 137.

Dulcification. The combination of mineral acids with alcohol. Thus we have dulcified spirit of nitre, dulcified spirit of vitriol, &c.

Educoration. Expressive of the purification of a substance by washing with water.

Efferescence. An intestine motion which takes place in certain bodies, occasioned by the sudden escape of a gaseous substance.

Efflorescence. A term commonly applied to those saline bodies which become pulverulent on exposure to the air, in consequence of the loss of a part of their water of crystallization.

Elasticity. A force in bodies, by which they endeavour to restore themselves to the posture from whence they were displaced by any external force.

Elastic Fluids. A name sometimes given to vapours and gases. Vapour is called an *elastic fluid*; gas, a *permanently elastic fluid*.

Electric Attractions. A term used by Bergman and others to designate what is now expressed by the words *Chemical affinity*; which see.

Elements. The simple constituent parts of bodies which are incapable of decomposition; they are frequently called principles.

Eliguation. An operation by which one substance is separated from another by fusion. It consists in giving the mass a degree of heat that will make the more fusible matter flow, and not the other.

Elutriation. The operation of reducing metallic ores or other substances to powder, and then mixing them with water, so that the lighter parts, which are capable of suspension, may be poured off, and thus separated from the grosser particles.

Empyreuma. A peculiarly disagreeable smell arising from the burning of animal and vegetable matter in close vessels.

Enloupelle. A copper vessel with a small orifice, and partly filled

with water. It is made hot, in order that the vapour of the water may rush out with violence, and carry a stream of air with it to increase the intensity of fires. It is an instrument of great antiquity.

Essences. In chemistry and pharmacy, essences are the essential oils, obtained by distillation, from odoriferous vegetable substances.

Essential Salts. The saline substances found in plants, and held in solution by the water in which they are infused. They are obtained by evaporation and cooling.

Ethers. Volatile liquids formed by the distillation of some of the acids with alcohol.

Evaporation. The conversion of fluids into vapour by heat. See page 43.

Euchlorine. A compound of chlorine and oxygen, consisting of about 82 chlorine and 18 oxygen. It may with propriety be called the protoxide of chlorine, as there are three other distinct compounds of these gaseous substances, each possessing more oxygen than euchlorine.

Eudiometer. An instrument invented by Dr. Priestley for determining the purity of any given portion of atmospheric air.

Expression. A term used in pharmacy, denoting the act of forcing out the juices and oils of plants by means of a press. By a similar term the *expressed* are distinguished from the *essential* oils.

Exsiccation. The act of drying moist bodies.

Obs. It is effected in two ways; by exhaling the aqueous particles by the application of heat on atmospheric air, and by absorbing the moisture with soft and spongy substances. Thus, small matters are dried by chemists with bibulous paper; and larger masses, by spreading them on tablets of chalk.

Extracts. The soluble parts of vegetable substances, first dissolved in spirit or water, and then reduced to the consistence of a thick syrup or paste by evaporation.

Fat. An oily concrete animal substance, composed of oil and carbon. See *Animal Oils*, page 240.

Fermentation. A peculiar spontaneous motion which takes place in all vegetable matter when exposed for a certain time to a proper degree of temperature. See page 229.

Fibrin. That white fibrous substance which is left after freely washing the coagulum of the blood, and which chiefly composes the muscular fibre. See page 234.

Filtration. A chemical process for the depuration of liquid substances.

Obs.—Bibulous paper supported by a funnel is commonly made use of; but for expensive liquors chemists gene-

rally use a little carded cotton lightly pressed into the tube of a glass funnel. The valuable concentrated acids should be filtered through pounded glass.

Fixity. A term applicable to that property of some bodies of bearing a great heat without being volatilized.

Flowers. Chemically speaking, flowers are solid dry substances reduced to a powder by sublimation. Thus, we have flowers of arsenic, of sal-ammoniac, of sulphur, &c., which are arsenic, sal-ammoniac, and sulphur, unaltered except in appearance.

Fluates. Salts formed by the combination of any base with fluoric acid.

Fluidity. A term applied to all liquid substances. Solids are converted to fluids by combining with a certain portion of caloric.

Flux. A substance which is mixed with metallic ores, or other bodies, to promote their fusion; as an alkali is mixed with silica in order to form glass.

Fossil. A term which was formerly considered to be partly synonymous with *mineral*; but now chiefly employed to denote those animal and vegetable remains of a former world, which have preserved their original forms, though buried within the earth and converted in some measure into substances similar to the matrices in which they are found.

Fuliginous. A term sometimes made use of in describing certain vapours which arise in chemical operations, having the thick appearance of smoke.

Fulmination. Thundering or violent explosion. We have fulminating silver, fulminating gold, and other fulminating powders, which explode with a loud report by friction, or when slightly heated. See Experiment.

Furnaces. Vessels of various forms for the fusion of ores, or other operations which require heat.

———— (*blast*), are built for making iron, smelting ores, &c. They are so contrived that their heat is much increased by means of powerful bellows. A blacksmith's forge is a kind of blast furnace.

———— (*wind*). Chemical furnaces for intense heats, so constructed that they draw with great force, without the use of bellows.

Fusion. The state of a body which was solid in the temperature of the atmosphere, but rendered fluid by the artificial application of heat.

Gallates. Salts formed by the combination of any base with gallic acid.

Galvanism. A new science which offers a variety of phenomena, resulting from different conductors of electricity placed in

different circumstances of contact; particularly the nerves of the animal body. See page 59.

Gangue. A term made use of to denote the stony matter which fills the cavities, and accompanies the ores in the veins of metals.

Gas. All solid substances, when converted into permanently elastic fluids by caloric, are called gases.

Gaseous. Having the nature and properties of gas.

Gasometer. A name given to a variety of utensils and apparatus contrived to measure, collect, preserve, or mix the different gases.

Gasometry. The science of measuring the gases.

Gelatine. A chemical term for animal jelly. It exists particularly in the tendons and the skin of animals. See page 236.

Glass. Some metallic oxides, when fused, are called *glass*. They have somewhat of resemblance to common glass.

—, **Phosphoric.** A vitreous, insipid, insoluble substance, procured by boiling down phosphoric acid to a syrup, and then fusing it by an increased heat.

— **Gall.** See *Sandiver*; with which it is synonymous.

Glucine. The pure base of the earth called glucina.

Gluten. A vegetable substance somewhat similar to animal gelatine. It is the gluten in wheat flour which gives it the property of making good bread, and adhesive paste. Other grain contains a much less quantity of this nutritious substance.

Graduation. A process, by evaporation, of bringing fluids to a certain degree of consistence, in order to separate more easily the substances they hold in solution.

— The division of a scale or measure into decimal or other regular parts.

Grain. The *smallest* weight made use of by chemical writers. See Table of Weights, &c. page 297.

Granulation. The operation of pouring a *melted* metal into water, in order to divide it into small particles for chemical purposes. Tin is thus granulated by the dyers before it is dissolved in the proper acid.

Gravity. That property by which bodies move towards each other, in proportion to their respective *quantities* of matter. This is the property by which bodies fall to the earth.

— (**Specific**). This differs from absolute gravity inasmuch as it is the weight of a given *measure* of any solid or fluid body, compared with the same measure of distilled water. It is generally expressed by decimals. See page 3.

Gums. Mucilaginous exudations from certain trees. Gum con-

sists of lime, carbon, oxygen, hydrogen, and nitrogen, with a little phosphoric acid.

Heat, Matter of. See *Caloric*.

Hepar. The name formerly given to the combination of sulphur with alkali. It is now called sulphuret of potash, &c.

Hepatic Gas. The old name for sulphuretted hydrogen.

Hermetically. A term applied to the closing of the orifice of a glass tube, so as to render it air-tight. Hermes, or Mercury, was formerly supposed to have been the inventor of chemistry; hence, a tube which was closed for chemical purposes was said to be Hermetically or chemically sealed. It is usually done by melting the end of the tube by means of a blow-pipe.

Hydrates. Those substances which have formed so intimate an union with water, as to solidify the water and render it one of their component parts, are called hydrates. Common slaked lime is properly a hydrate of lime.

Hydriodates. Compounds formed by the union of certain substances with hydriodic acid.

Hydro-Carbonates. Combinations of carbon with hydrogen are described by this term. Hydro-carbonate gas is procured from moistened charcoal by distillation.

Hydrogen. A simple substance; one of the constituent parts of water. See page 171.

——— (*Gas*). Solid hydrogen united with a large portion of caloric. It is the lightest of all the known gases. See page 171, &c.

Hydrogenized Sulphurets. Certain bases combined with sulphuretted hydrogen.

Hydrourets. Combinations of sulphur and hydrogen with the earths and alkalies.

Hydrometers. Instruments for ascertaining the specific gravity of spirituous liquors or other fluids.

Hydro-Oxides. Metallic oxides combined with water.

Hygrometers. Instruments for ascertaining the degree of moisture in atmospheric air.

Hygroscope. This term is sometimes considered synonymous with *Hygrometer*, but the instruments are different; or the account of an improved hygroscope invented by Professor Leslie. See his "Short Account of Experiments," page 106.

Hyper-oxygenized. A term applied to substances which are combined with the largest possible quantity of oxygen. We had formerly muriatic acid, oxygenized muriatic acid, and hyper-oxygenized muriatic acid. These latter terms are, however, gradually falling into disuse, and the terms chlorine and euechlorine are substituted for them.

- Ignition.** The incandescence of a body, produced by extrinsic means, without change of its chemical constitution.
- Incandescence.** The shining or glowing appearance of a heated substance.
- Incineration.** The burning of vegetables for the sake of their ashes. It is usually applied to the burning of kelp on the sea-coast for making mineral alkali.
- Incompatible Salts.** Salts which cannot exist together in solution without mutual decomposition being produced.
- Inflammation.** A phenomenon which takes place on mixing certain substances. The mixture of oil of turpentine with strong nitrous acid produces an instance of this peculiar chemical effect.
- Infusion.** A simple operation to procure the salts, juices, and other virtues of vegetables by means of water.
- Insolation.** Sometimes used to denote that exposure to the sun which is made in order to promote the chemical action of one substance upon another.
- Integragt Particles.** The most minute particles into which any compound substance can be divided *similar* to each other, and to the substance of which they are parts, are termed the integragt particles: *e.g.* The smallest atom of powdered marble is still marble, but if by chemical means the calcium, the carbon, and the oxygen of this marble be separated, we shall then have the *elementary* or constituent particles.
- Intermedates.** A term made use of when speaking of chemical affinity. Oil, for instance, has no affinity to water unless it be previously combined with an alkali; it then becomes soap, and the alkali is said to be the *intermedium* which occasions the union.
- Iodides.** Compounds formed by the union of any substance with *iodine*.
- Ittrium.** The undecomposable base of the earth called yttria.
- Kali.** A genus of marine plants which is burnt for the preparation of mineral alkali. The alkali is afterwards obtained by lixiviating the ashes, and then concentrating the saline liquor by evaporation.
- Kelp.** An impure mineral alkali, procured on several of the coasts of this island by the incineration of the *sea wrack* (the *Fucus* of Linnæus) and other sea weeds; and the infusing the ashes in powerful furnaces constructed for the purpose.
- Kermes Mineral.** A medicinal preparation, formed by the union of sulphuret of antimony and potash.
- Laboratory.** A place properly fitted up for the performance of chemical operations.
- Lactates.** Salts formed by the combination of any base with lactic acid.
- Lakes.** Certain colours made by combining the colouring matte

of cochineal, or of certain vegetables, with pure alumina, or with oxide of tin, zinc, &c.

Obs.—The principal lakes are, carmine, Florence lake, and lake from madder.

Lamp, Argand's. A lamp much used for chemical experiments, made on the principle of a wind furnace; and thus produces a great degree of light and heat without smoke.

Lens. A glass convex on both sides, for concentrating the rays of the sun; employed by chemists in fusing refractory substances which cannot be operated upon by an ordinary degree of heat.

Levigation. The mechanical process of grinding down of hard substances to an impalpable powder on a stone with a muller, or in a mill adapted to the purpose.

Light. The agent of vision.

Obs.—Some philosophers regard light as consisting of particles of inconceivable minuteness, emitted in succession by luminous bodies, which move in straight lines, at the rate of 200,000 miles per second. Others, that it consists in certain undulations, communicated by luminous bodies to an ethereal fluid which fills all space. See page 48.

Liquefaction. A term in some instances synonymous with the word *fusion*, in others with the word *deliquescence*, and in others again with the word *solution*. See pp. 37 and 43.

Litharge. An oxide of lead which appears in a state of vitrification. It is formed in the process of separating silver from lead.

Lixivation. The application of water to the fixed residues of bodies, for the purpose of extracting the saline part.

Lixivium. A fluid impregnated with an alkali, or with a salt.

Lute. A composition for closing the junctures of chemical vessels, to prevent the escape of gas or vapour in distillation.

Obs.—Glazier's putty is a very good lute for all the common purposes of a laboratory; but it is necessary that the whiting be made thoroughly dry before it be mixed with the oil. Linseed oil and sifted slacked lime, well mixed, and made thoroughly plastic, form an excellent coating for retorts: if made thicker, this mixture is an impenetrable luting, that is not liable to crack.

Maceration. The steeping of a solid body in a cold fluid.

Magnesium. The undecomposable base of magnesia.

Malates. Salts formed by the combination of any base with malic acid.

Malleability. That property of metals which gives them the capacity of being extended and flattened by hammering. See *Metals*, p. 134.

Martial. An old term for chemical preparations of iron. See *Chalybeate*.

Massicot. A name given to the *yellow* oxide of lead, as minium is applied to the *red* oxide.

Matrass. Another name for a bolt-head; which see.

Matrix. The bed in which a metallic ore is found.

Matt. That mass of metal which separates from the scorise in smelting ores without previous roasting.

Menstruum. The fluid in which a *solid* body is dissolved: *e. g.* Water is a menstruum for salts, gums, &c., and spirit of wine for resins.

Metallic Oxides. Metals combined with oxygen. By this process they are generally reduced to a pulverulent form; are changed from combustible to incombustible substances; and receive the property of being soluble in acids.

Metallurgy. The art of extracting and purifying metals.

Mineral. Any natural substance of a metallic, earthy, or saline nature, whether simple or compound, is deemed a mineral.

Mineralizers. Metallic substances are said to be mineralized when deprived of their usual properties by combination with other substances.

Mineralogy. The science of fossils and minerals.

Mineral Waters. Waters holding some metal, earth, or salt in solution.

Minium. A name given to the red oxide of lead, commonly called red-lead.

Molecule. The molecules of bodies are those ultimate particles of matter which cannot be decomposed by any chemical means.

Molybdates. Salts formed by the combination of any base with the molybdic acid.

Mordants. Substances which have a chemical affinity for particular colours; they are employed by dyers as a bond to unite the colour with the cloth intended to be dyed. Alum is of this class.

Mortar Cement. A mixture of lime and siliceous sand, used in masonry for the cementing together the stones and bricks of a building.

Mother-Waters, or Mothers. The liquors left after the crystallization of any salts.

Mucilage. A glutinous matter obtained from vegetables, transparent and tasteless, soluble in water, but not in oils, or in spirit of wine.

Mucites. Salts formed by the combination of any base with the mucous or saccholactic acid.

Mucus. One of the primary animal fluids, perfectly distinct from gelatin (Dr. Bostock).

Obs.—The subacetate of lead does not affect gelatin; on the other hand, tannin, which is a delicate test of gelatin, does not affect mucus. Both these reagents however, precipitate albumen; but the bichloride of mercury,

which will indicate the presence of albumen, dissolved in 2000 parts of water, precipitates neither water nor gelatin.

Muffle. A small earthen oven, made and sold by the crucible manufacturers. It is to be fixed in a furnace, and is useful for cupellation, and other processes which demand access of air.

Muriates. Salts formed by the combination of any base with muriatic acid.

Natron. Native carbonate of soda, of which there are two kinds, the common and radiated.

Neutralize. When two or more substances mutually disengage each other's properties, they are said to neutralize one another: *e. g.* an acid and an alkali combined in such proportions that the compound does not change the colour of litmus or violets.

Neutral Salt. A substance formed by the union of an acid with an alkali, an earth, or a metallic oxide, in such proportions as to saturate both the base and the acid.

Nitrates. Salts formed by the combination of any base with nitric acid.

Nitrogen. A simple substance, by the French chemists called azote. It enters into a variety of compounds, and forms more than three parts in four of atmospheric air. See page 175.

Ochre. An ore of iron.

Odour. The emanation of an odoriferous body is generally ascribed to a portion of the body itself, converted into vapour. M. Robiquet says that in many cases the odour is owing, not to the substance itself, but to a gas or vapour resulting from its combination with an appropriate vehicle, capable of diffusion in space.—*Ann. De Chimie et de Phy.* xv. 27.

Oil. The distinctive characters of oil are inflammability, insolubility in water, and fluidity, at least in a moderate temperature.

Obs.—Oils are distinguished into fixed or fat oils, which do not rise in distillation at the temperature of boiling water, or under 3208 by themselves. See page 240.

Ores. The mineral bodies from which metals are extracted.

Opacity. The property of obstructing the passage of light.

Oxalates. Salts formed by the combination of any base with oxalic acid.

Oxides. Substances combined with oxygen, in a proportion not sufficient to produce acidity.

Oxidize. To combine oxygen with a body without producing acidity: in this respect it differs from acidification.

Oxidation. The operation by which any substance is combined with oxygen, in a degree not sufficient to produce acidity. See page 168.

Oxygen. A simple substance composing the *greatest* part of water, and part of atmospheric air. See page 167.

Oxygen Gas. Oxygen converted to a gaseous state by caloric. It is also called vital air. It forms nearly one-fourth of atmospheric air. See page 167.

Oxygenizable. A term applicable to all bodies that combine with oxygen, and do not emit flame during the combination.

Oxygenize. To acidify a substance by oxygen. Synonymous with *Oxygenate*; but the former is the better term.

Oxygenation. The production of acidity by oxygen.

Obs.—This word is often used instead of oxidation, and frequently confounded with it; but it differs in being of more general import, as every union with oxygen, whatever the product may be, is an oxygenation; but oxidation takes place only when an oxide is formed.

Parting. The operation of separating gold from silver by means of nitrous acid, and other mediums.

Pelican. A glass alembic with a tubulated capital, from which two opposite and crooked arms pass out, and enter again at the swell of the vessel. The instrument is designed for operations of cohobation, and is calculated to save the trouble of frequently luting and unluting the apparatus. It is now seldom used.

Pellule. A thin skin which forms on the surface of saline solutions and other liquors, whenever they are concentrated to a certain point by means of the evaporation of a portion of the fluid.

Phlogiston. The supposed general inflammable principle of Stahl.

Phlogisticated Alkali. A Prussiate of potash.

Gas, nitrogen or azote.

Phosgene Gas. Chlorocarbonous acid.

Phosphates. Salts formed by the combination of any base with phosphoric acid.

Phosphites. Salts formed by the combination of any base with phosphorous acid.

Phosphorescence. A light emitted by some substances at common temperatures, and which gives rise to an appearance thus called. See page 53.

Phosphurets. Substances formed by an union with phosphorus. Thus we have phosphuret of lime, phosphuretted hydrogen, &c.

Photometer. An instrument contrived for measuring the comparative intensity of light.

Piumbago. Carburet of iron, or the *black lead* of commerce. See page 248.

Pneumatic. Any thing relating to the airs and gases.

—trough. A vessel filled in part with water or mer-

cury, for the purpose of collecting gases, so that they may be readily removed from one vessel to another.

Potassium. The metallic base of the alkali called potash.

Pottery. The art of making earthenware, and intimately connected with chemistry, not only from the great use made of earthen vessels by chemists, but also because all the processes of this art, and the means of perfecting, are dependent on this science.

Powder of Algaroth. The white oxide of antimony, thrown down from the muriate by water.

Precipitate. When a body is dissolved in a fluid is either whole or in part made to separate and fall down in the concrete state, this falling down is called precipitation, and the matter thus separated is called a precipitate.

———— *pe se*, red oxide of mercury by heat.

Precipitation. That chemical process by which bodies dissolved, mixed, or suspended in a fluid, are separated from that fluid, and made to gravitate to the bottom of the vessel.

Prussiates. Salts formed by the combination of any base with prussic acid.

Putrefaction. The spontaneous decomposition of such animal or vegetable matters as exhale a fetid smell. See page 233.

Pyrites. Native compounds of metal with sulphur. Some are sulphurets of iron, and others sulphurets of copper, with a portion of alumina and silica. The former are worked for the sake of the sulphur, and the latter for sulphur and copper. They are also called Marcasites and Fire-stone.

Pyrites, martial. That species of pyrites which contains iron for its basis.

Pyrometer. An instrument invented by Mr. Wedgwood for ascertaining the degrees of heat in furnaces and intense fires. See *Philosoph.* *Trans.* vol. lxii. and lxiv.

Pyrophor. Compound substances which heat of themselves, and take fire on the admission of atmospheric air. See Weigleb's *System of Chemistry*, quarto, page 622; &c.

Obs.—Some very good pyrophori may be made by simply mixing three parts of alum with one of wheat flour, calcining them in a common phial till the blue flame disappears, keeping it well stopped with a good cork, when cold. If this powder be exposed to the atmosphere, the sulphur attracts moisture from the air, and generates sufficient heat to kindle the carbonaceous matter mingled with it.

Pyroscope. An instrument invented by Mr. Leslie for measuring the pulsatory commotion of the air, or the intensity of the heat darting continually from the fire into a room: it will also mark the pulsations from a cold surface.

Quartation. A term used by refiners in a certain operation of parting. See *Lewis's Com. Tech.* page 135.

Quartz. A name given to a variety of siliceous earths usually mixed with a small portion of lime or alumina. Mr. Kirwan confines the term to the *purer* kind of silica. Rock crystal and the amethyst are species of quartz. Professor Jamieson divides this mineral genus into two species, viz., Rhomboidal quartz, and indivisible quartz.

Radicals. A chemical term for the *Elements* of bodies.

compound. When the base of an acid is composed of two or more substances, it is said that the acid is formed of a *compound radical*. The sulphuric acid is formed with a *simple radical*; but the vegetable acids, which have radicals composed of hydrogen and carbon, are said to be acids with compound radicals. It is sometimes called the base of the acid, but base is a term of more extensive signification.

Rancidity. The change which oils undergo by exposure to the air.

Reagents. Substances which are added to mineral waters or other liquids as tests to discover their nature and composition. See Gottling's *Description of a portable Chest of Chemistry*, &c. 12mo., 1791.

Realgar. A native mineral known also by the name of red orpiment; or a red sulphuret of arsenic.

Receivers. Globular glass vessels adapted to retorts for the purpose of preserving and condensing the volatile matter raised in distillation. See fig. pl.

Rectification. The re-distilling a liquid to render it more pure, or more concentrated, by abstracting a *part* of it only.

Reduction or Revivification. The process of restoring metallic oxides to their natural state, and is usually effected by means of charcoal and fluxes.

Refining. The process of separating the perfect metals from other metallic substances, by what is called cupellation.

Refractory. A term applied to earths or metals that are either infusible, or that require an extraordinary degree of heat to change or melt them.

Refrigeratory. A vessel which, by containing cold water, answers the purpose of condensing the vapour or gas that arises in any process of distillation. A common worm-tub is a refrigeratory.

Registers. Openings in chimneys, or other parts of chemical furnaces, with sliding doors, to regulate the quantity of atmospheric air admitted to the fire-place, or to open or shut the communication with the chimney at pleasure.

Regulus. A pure metallic substance, freed from all extraneous matters.

Obs.—This name was introduced by all chemists, who, expecting always to find gold in the metal collected at the bottom of the crucibles after fusion, called the metal thus collected regulus, as containing gold, the king of metals.

Repulsion. A principle whereby the particles of bodies are prevented from coming into actual contact. It is thought to be owing to *caloric*, which has been called the repulsive power.

Residuum. What is left in a pot or retort after the volatile part has been drawn off: *e. g.* The sulphate of potash, which remains in the pot after the distillation of nitrous acid, is called the residuum. It is sometimes called the *caput mortuum*.

Respiration. An animal function, which consists in the alternate inhalation of a portion of air into an organ called the lungs, and its subsequent exhalation.

Obs.—The venous blood which enters the limb from the pulmonary artery, is charged with carbon, to which it owes its dark purple colour.

Resins. Vegetable juices concentered by evaporation either spontaneously or by fire. Their characteristic is solubility in alcohol and oils, and not at all in water.

Retort. A vessel in the shape of a pear, with its neck bent downwards, used in distillation; the extremity of which neck fits into that of another vessel or bottle called a receiver.

Obs.—The most capacious part of the retort is called its belly. Its upper part is called the arch or roof of the retort, and the bent part is the neck. See pl. I. fig. 3.

Reverberatory. An oven or furnace in which the flame from the combustible is confined by a dome that occasions it to be beat down upon the floor of the furnace before it passes into the chimney. Some are so contrived that the flame is made to return or reverberate upon the matter under operation.

Revivification. See *Reduction*; terms nearly synonymous; though "revivification" is generally used when speaking of the reduction of the oxides of mercury.

Roasting. A preparative operation in metallurgy to dissipate the sulphur, arsenic, &c., with which a mineral may be combined.

Rock-Crystal. Crystallized silica. See *First Class of Mineralogy*.

Saccholactates, or Mucites. Salts formed by the combination of any base with saccholactic or mucous acid.

Sal Alembroth. A compound muriate of mercury and ammonia.

Sal De Duobus, } Names originally given to the salt now called
Sal Polychrest, } sulphate of potash.

Salifiable Bases. Those metals, alkalies, and earths capable of combining with acids, and forming salts, are thus termed.

Saltus. Partaking of the properties of a salt.

Salmiac. A word sometimes used for sal ammoniac.

Salts, Neutral. A class of substances formed by the combination to saturation of an acid to an alkali, an earth, or other salifiable base.

Salts, Triple. Salts formed by the combination of an acid with

two bases or radicals. The tartrate of soda and potash (Rochelle salt) is an instance of this kind of combination.

Obs.—The term salt has usually been employed to denote a compound, in definite proportions, of acid matter, with an alkali, earth or metallic oxide. When the proportion of the constituents is so adjusted that the resulting substance does not affect the colour of the infusion of litmus, or red cabbage, it is then called a neutral salt. When the predominance of acid is evinced by the reddening of these infusions, the salt is said to be acidulous, and the prefix *super* or *bi* is used to indicate this excess of acid. When, on the contrary, the acid matter is in defect or short of the necessary quantity to neutralize the alkalinity of the base, the salt is then said to be with excess of base, and the prefix *sub* is attached to its name.

Sand Bath, } See *Bath*.
— *Heat.* }

Sandiver, or Glass Gall. A matter, composed of different salts, which rises as a pellicle on the surface of the pots in which glass is melted. It is used as a flux in the fusion of ores, and for other purposes.

Sap-Colours. A name given to various expressed vegetable juices of a viscid nature; which are inspissated by slow evaporation for the use of painters, &c. Sap-green, gamboge, &c., are of this class.

Saponaceous. A term applied to any substance which is of the nature or appearance of soap.

Saturation. The act of impregnating a fluid with another substance, till no more can be received or imbibed. A fluid which holds as much of any substance as it can dissolve, is said to be saturated with that substance. A solid may in the same way be saturated with a fluid.

Sebates. Salts formed by the combination of any base with sebaceous acid.

Selenite. A salt existing in spring water, formed by sulphuric acid and lime. Its proper chemical name is sulphate of lime.

Semi-Metal. A name formerly given to those metals which, if exposed to the fire, are neither malleable, ductile, nor fixed. It is now obsolete.

Siliceous Earths. A term used to describe a variety of natural substances composed chiefly of silica; as quartz, flint, sand, &c.

Silicium. The undecomposable base of rock crystal, or of the earth called silica.

Simple Substances. See *Elements*.

Smelting. The fusing of ores for the purposes of separating the metals they contain, from the sulphur and arsenic with which they are mineralized, and also from other heterogeneous matter.

Sodium. The metallic base of the alkali called soda.

Solubility. A characteristic of most salts. See the next word.

Solution. The perfect union of a solid substance with a fluid. Salts dissolved in water are proper examples of solution.

Spar. A name formerly given to various crystallized stones; such as the fluor spar, the adamantine spar, &c., which are now distinguished by more appropriate names.

Specific Gravity. The density of the matter of which any body is composed, compared with the density of another, assumed as the standard. See page 9.

Spelter. The commercial name of metallic zinc.

Spirits. A term used by the early chemists to denote all volatile fluids collected by distillation.

——, *proof.* A term made use of to describe such ardent vinous spirits as are of the same strength, as the brandy of commerce, or of the specific gravity of 0.930, water being 1.000.

Stalactites. Certain concretions of calcareous earth found suspended like icicles in vaults and caverns. They are formed by the oozing of water, charged with calcareous particles, through the crevices, and gradually evaporating, leave these particles behind.

Stannane. Protochloride of tin.

Steam. See *Caloric* and *Vapour*, pp. 18, 43.

Steatites. A mineral composed of silica, iron, magnesia, &c. It is also called French chalk, Spanish chalk, and soap-rock.

Steel. A modification of iron, of which our present knowledge is not very concise, notwithstanding the researches of some very eminent chemists.

Stibium. Antimony.

Stratification. A chemical operation by which bodies are placed in a condition to act mutually upon each other by being arranged layer by layer, stratum super stratum, as is practised by metallurgists.

Strontium. The undecomposable base of the earth called Strontites.

Sub-salts. Salts with less acid than is sufficient to neutralize their bases or radicals.

Suberates. Salts formed by the combination of any base with the suberic acid.

Sublimate. A name given to some mercurial preparations.

Sublimation. A process by which certain volatile substances are raised by heat, and again condensed by cold into a solid form: *e.g.* Flowers of sulphur are made in this way. The soot of our common fires is a familiar instance of this process.

Succinates. Salts formed by the combination of any base with the succinic acid.

Sugar. The well-known constituent of a variety of vegetables. It is composed of oxygen, hydrogen, and carbon. See page 220.

Sulphates. Salts formed by the combination of any base with the sulphuric acid.

Sulphites. Definite compounds of sulphurous acid with the bases.

Sulphur. A simple inflammable body, of great importance in chemistry and the arts. See page 184.

Sulphurets. Combinations of alkalies, or metals, with sulphur.

Sulphuretted. A substance is said to be sulphuretted when it is combined with sulphur. Thus we say sulphuretted hydrogen, &c.

Super-salts. Salts with an excess of acid, as the super-tartrate of potash. See *Salts, Neutral*.

Synthesis. The examination of a body; by *dividing* it into its component parts, it is called analysis; but when it is attempted to prove the nature of a substance by the *union* of its principles, the operation is called synthesis.

Syphon. A bent tube used by chemists and other persons for drawing liquids from one vessel into another. See fig. pl. I.

Tannin. One of the immediate principles of vegetables, first discovered by Seguin from the gallic acid, with which it had been confounded under the name of the astringent principle. See page 224.

Tanning. The process of making leather from the hides of animals.

Tarras or Terras. A volcanic earth used as a cement.

Tartrates. Salts formed by the combination of any base with the acid of tartar.

Tellureted. A term applied to certain compounds formed by the agency of Tellurium.

Obs.—Tellurium and hydrogen unite, and produce a gaseous compound called tellureted hydrogen gas. It also unites by fusion to nearly its own weight of sulphur, producing a striated mass of the colour of lead.

Temperature. A definite degree of sensible heat as measured by the thermometer.

Tenacity, is a term used when speaking of glutinous bodies. It is also expressive of the adhesion of one substance to another. See *Cohesion*.

Test. The name of whatever is employed in chemical experiments to detect the several ingredients of any composition.

Test-papers. Papers impregnated with certain chemical reagents; such as litmus, turmeric, radish, &c. They are used to dip into fluids to ascertain by a change of colours the presence of acids and alkalies.

Thermometer. An instrument to show the relative heat of bodies. Fahrenheit's thermometer is that chiefly used in England. (See page 33.) Other thermometers are used in different parts of Europe. For the difference in the scale of these thermometers, see the Table at page 35.

Tinical. Crude borax; it is imported from the East Indies, in yellow greasy crystals.

Tinctures. Solutions of substances in spirituous menstrua.

Tinglass. Bismuth.

Torrefaction. An operation similar to roasting; which see.

Tritortum. A vessel used for the separation of two fluids which are of different densities. The same operation may be performed by a common funnel.

Trituration. The operation whereby substances are united by friction. Amalgams are made by this method.

Tube of Safety. A tube open at both ends, inserted into a receiver, the upper end communicates with the external air, and the lower part immersed in water. The intention of this instrument is to prevent accidents from too sudden condensation or rarefaction during an operation. It is commonly called Welter's tube; and is now more frequently used in a curved form.

Tubulated. Retorts with a hole at the top for inserting the materials to be operated upon without taking them out of the sand heat, are called *tubulated* retorts.

Tungstates. Salts formed by the combination of any base with tungstic acid.

Tutenag. An Indian name for zinc. Chinese copper is also called by this name, which is a compound of copper, tin, and arsenic, much resembling silver in colour.

Vacuum. A space unoccupied by matter. The term is generally applied to the exhaustion of atmospheric air by chemical or philosophical means.

Vapour. A term used to denote such exhalations only as can be condensed and rendered liquid again at the ordinary atmospheric temperature, in opposition to those which are *permanently* elastic. See *Caloric*, page 18, *et seq.*

Vats. Large vessels, generally of wood, employed for making infusions, &c.

Vegetable Kingdom. For the principal products of vegetation, see *Sugar*, page 220, *et seq.*

Vegetation, Saline. See Memoir on this subject, in the *Journal de Physique* for Oct. 1788, by M. Chaptal; entitled *Observations on the influence of the Air and Light upon the Vegetation of Salts*.

Vital Air. Oxygen gas. The empyreal or fire-air of Scheele and the dephlogisticated air of Priestley. See page 167.

Vitrification. When certain mixtures of solid substances, such as silica and an alkali, are exposed to an intense heat, so as to be fused, and become glass, they are then said to be vitrified, or to have undergone vitrification.

Vitriolated Tartar. The old name for sulphate of potash.

Vitriols. A class of substances, either earthy or metallic, which

are combined with the vitriolic acid. Thus, there is vitriol of lime, vitriol of iron, vitriol of copper, &c. These salts are now called Sulphates, because the acid which forms them is called sulphuric acid.

Volatile Alkali. Another name for ammonia. See page 66.

Volatile Salts. The commercial name for carbonate of ammonia. See page 66.

Volatility. A property of some bodies which disposes them to assume the gaseous state. This property seems to be owing to their affinity for caloric.

Volume. A term made use of by modern chemists to express the space occupied by gaseous or other bodies.

Union, Chemical. When a mere mixture of two or more substances is made, they are said to be mechanically united; but when each of either substances forms a component part of the product, the substances have formed a *chemical union*.

Ustulation. The roasting of ores, to separate the arsenic, sulphur, and whatever else is of a volatile nature that is connected with and mineralizes the metal. When the matter is preserved which flies off, the process is called sublimation; but when this matter is neglected, the operation is called ustulation.

Wash. The technical term for the fermented liquor, of whatever kind, from which spirit is intended to be distilled.

Water. The most common of all fluids, composed of 88 parts of oxygen and 11 of hydrogen.

—, **Mineral.** Waters which are impregnated with mineral and other substances are known by this appellation. These minerals are generally held in solution by carbonic, sulphuric, or muriatic acid.

—, **of Crystallization.** Many salts acquire a certain portion of water to enable them to retain the crystalline form, and this is called their water of crystallization.

Obs.—Some salts retain their water of crystallization so feebly, that it flies off on exposure to the air, and they fall to powder. These are the efflorescent salts; others have so great an affinity for water, that their crystals attract more from the air, in which they dissolve. These are the deliquescent.

Way Dry. A term used by chemical writers when treating of analysis or decomposition. By decomposing in the dry way, is meant, by the agency of fire.

—, **Humid.** A term used in the same manner as the foregoing, but expressive of decomposition in a fluid state, or by means of water and chemical re-agents, or tests.

Welding Heat. That degree of heat in which two pieces of iron or of platinum may be united by hammering.

Wolfram. An ore of tungsten containing also the oxides of manganese and iron.

Worm Tub. A chemical vessel with a pewter worm fixed in the inside, and the intermediate space filled with water. Its use is to cool liquors during distillation. See *Refrigeratory*.

Wulfe's Apparatus. A contrivance for distilling the mineral acids and other gaseous substances with little loss; consisting of a train of receivers with safety pipes, connected together by tubes. For a full description of this most useful apparatus, see *Philosophical Transactions* for 1767.

Zaffre. An oxide of cobalt, mixed with a portion of siliceous matter. It is imported in this state from Saxony.

Zero. The point from which the scale of a thermometer is graduated.

Ex.—Celsius's and Reaumur's thermometers have their zero at the *freezing point*,—that is, at the point at which water freezes; while the thermometer of Fahrenheit has its zero at that point at which it stands when immersed in a mixture of snow and common salt. See *Table of the Correspondence of the Thermometers of Fahrenheit, Reaumur, and Celsius*, in "NEW LONDON MEDICAL AND SURGICAL DICTIONARY."

Zirconium. The pure base of the earth called zirconia. See page 270.

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